EFFECT OF EXTERNAL FIELDS UPON ALTERNATING CURRENT WATTMETERS

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EXTERNAL FIELDS
UPON
ALTERNATING CURRENT WATTMETERS

A THESIS

PRESENTED BY

GURDON A. BINDER *and* JOHN T. WALBRIDGE

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HAVING COMPLETED THE PRESCRIBED COURSE OF STUDY IN

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THE EFFECT OF
EXTERNAL FIELDS UPON
ALTERNATING CURRENT WATTMETERS.

This thesis comprises a series of tests made upon four different wattmeters in order to ascertain the effect of an external field upon the accuracy of the same. It is a well known fact that direct current recording wattmeters are materially effected by direct current fields. This is due to the fact that a direct current meter, which in reality is a direct current motor, has its fields magnetizedor demagnetized, depending upon the direction of the current producing the external field. However, so far as we could ascertain no extensive tests have been recorded showing the effect of external alternating current fieldsupon alternating current wattmeters. With this point in view several tests were made upon a Type K, Fort Wayne Meter, Type C. Westinghouse Meter, Thompson High Torque Test Meter, and a Type L, Sanamo Meter. The descriptions of these several meters are as follows:

THE FORT WAYNE METER.

TYPE K.

This meter is of the induction type with the rotating field. The main point of difference between this motor and other makes of the same type, is that instead of a flat disc, a cylindrical aluminum cup is used on the rotating member. The series and pressure coils are placed

21533

with their axes horizontal and pointing toward the center of the cup. Both are placed in the back part of the case. On the opposite side of the disc a permanent magnet is fixed and serves as a damper.

In order to compensate for static friction, an adjustable starting coil is connected in the shunt circuit of the meter. This coil is mounted on an adjustable core. By moving the end of this core, with reference to the main front coil, the meter can be adjusted for starting with very small loads. The connections are as shown in the diagram.

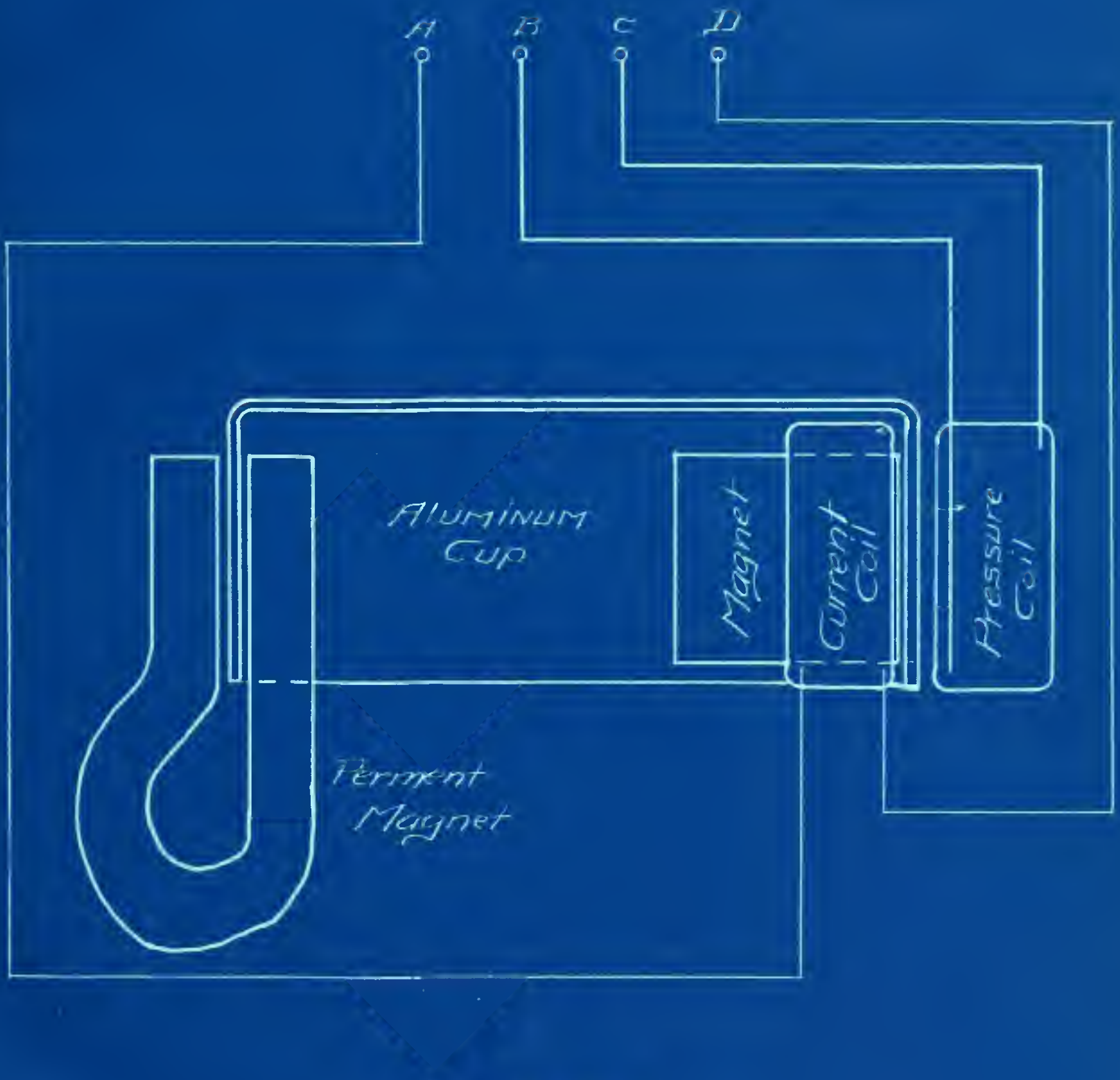
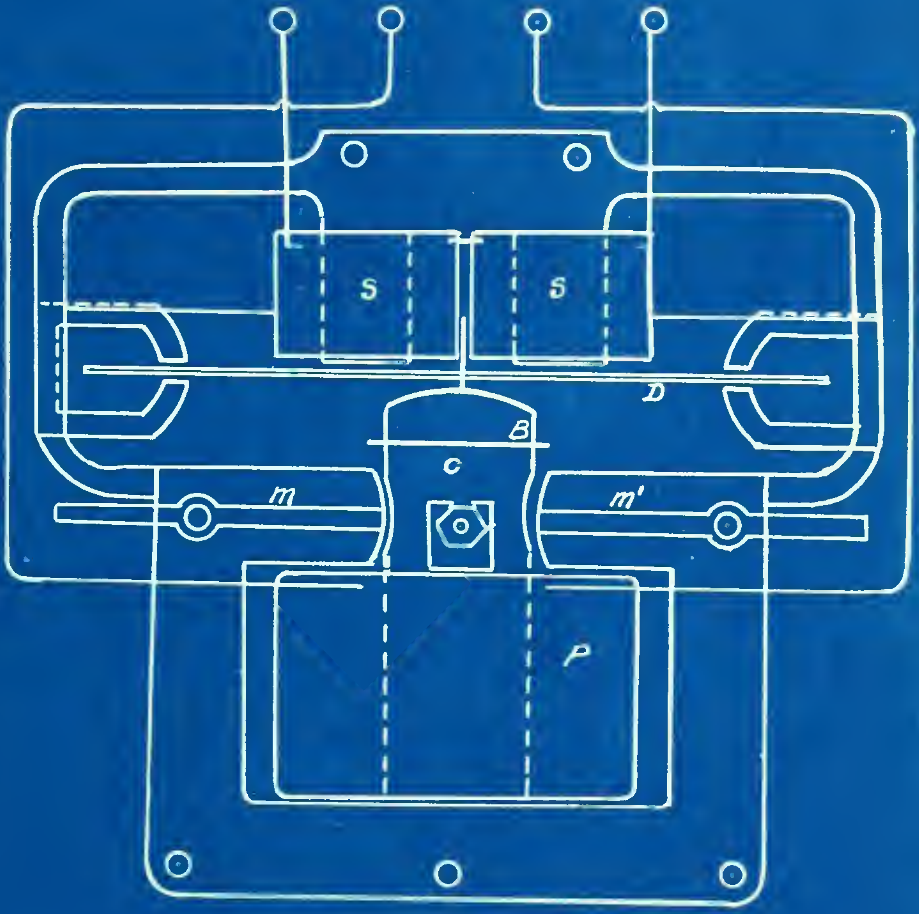


Diagram
of
FORT WAYNE METER
Nº

WESTINGHOUSE METER.

TYPE C.

The Westinghouse Meter upon which our test was made is of the induction type. The blue print given shows an outline of this meter with the circuit diagram. The rotating element consists of a light shaft carrying an aluminum disc which rotates between the poles of the series and pressure magnets, and between the poles of the damping magnets. On the blue print D represents the disc, P is the pressure coil and S is the series coil. The copper bucket, B, surrounds the laminated pole, C, and furnishes means of adjustments for differnet frequencies. If the circuit of this bucket is opened the meter will be adjusted for 125 cycles, if this circuit is closed the meter will be adjusted for 60 cycles. The small buckets shown on the outer poles at m and m' provide for friction compensation. The adjustment for friction is obtained by first opening the series circuit, then raising these buckets, m amd m', until the meter just starts upon the pressure current only and then lowering the buckets until the disc just stops. With this position of these buckets the torque due to the pressure current alone will not make the meter creep, but is nearly sufficient to compensate for all moving friction. The moving system is supported on a highly polished steel ball between cup shape jewels, thus making the friction almost negligible.



Circuit Diagram of "Westinghouse" Meter.

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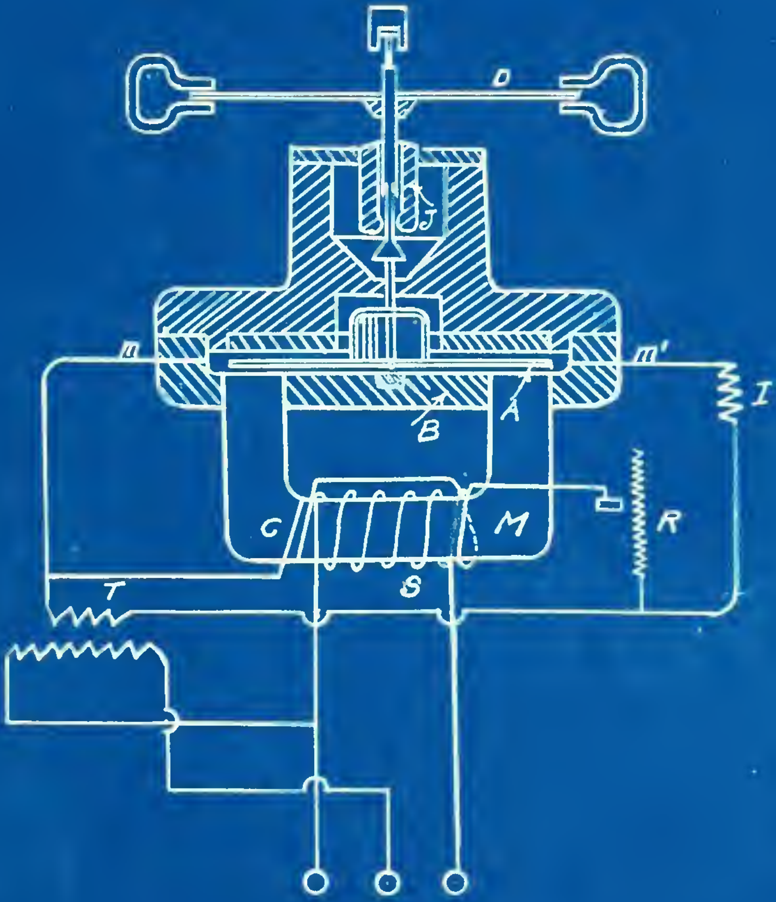
SANGAMO METER.

TYPE E.

This Sangmo Meter is of the mercury type. The blue print givens shows a partial vertical section together with an outline of the meter. The moving system consists of a light shaft carrying two disc D-D'. The upper disc D rotates between poles of two permement magnets as shown in the upper part of the diagram. The shaft on the disc is buoyed up by the mercury and the upper end of the shaft bearing against the jewel Bearing J. The two poles of the series magnet M project thru casings of the mercury chamber and are close to the under side of disc D. The series circuit consists of the single coil S wound on the laminated magnet M. T, is a small, low potentant step down transformer, the primary of which consists of the large number of turns of fine wire and is connected directly to the pressure posts of the meter. The secondary winding consists of only a few and in this case of only two turns of heavy wire. The small inductive coil I and the mercury chamber A connected in series constitutes the main circuit of the secondary of the transformer. The secondary E.M.F. of this transformer is small , but the secondary current is large because the inductance and resistance of the circuit are exceedingly small. This large secondary current enters one side of the mercury chamber A, flows across the Disc D' leaves at the opposite side of the mercury chamber.

In passing across the disc this current flows past the poles of the series magnet M, and the reaction between the series flux and the flux due to the secondary current produces the necessary torque' Friction compensation is obtained by means of the small coil C, which is connected thru the varible resistance R to the secondary terminals of the transformer.T.



Circuit Diagram of "Sangamo" Meter.

THOMPSON HIGH TORQUE TEST METER.

This meter was designed primarily for testing purposes. It is enclosed in a wooden case and equipped with a carrying handle and large connecting posts. There are three dials; on the large one, the pointer makes one revolution for each revolution of the disc. There are one hundred divisions on the dial so that the meter may be read to 1/100dth of a revolution. One of the small dials records revolutions and the other, tenths of revolutions.

In order to have this meter give accurate readings throughout a wide range of load, three current colis are wound on the two poles of the laminated magnet M. The coils have one common terminal at the point O. The other terminals are connected to the binding posts marked 1, 10, 20. The pressure coil P, of the meter is wound on the laminated magnet N.

The terminals are marked one ampere, ten amperes, and twenty amperes, and by making the proper connection it is possible to get very accurate readings anywhere between 1/10th ampere and 30 amperes load. The disc is made of a large flat circular piece of aluminum. The larger siae of this disc gives the meter its high torque. The disc is connected by means of a vertical shaft to the pointer, and rotates in the air gap between the series and pressure magnets. The torque is produced by the reaction between the series field and field of the eddy currents induced in the disc by the pressure

circuit. The meter is also fitted with a switch S, operated by means of a button on the top, by means of which the meter may be made to operate either on 25 cycles or 60 cycles. Whentthe button is turned to read 25 cycles a small induction coil is connected in series with the pressure coil. Permanent magnets are used as dampers.

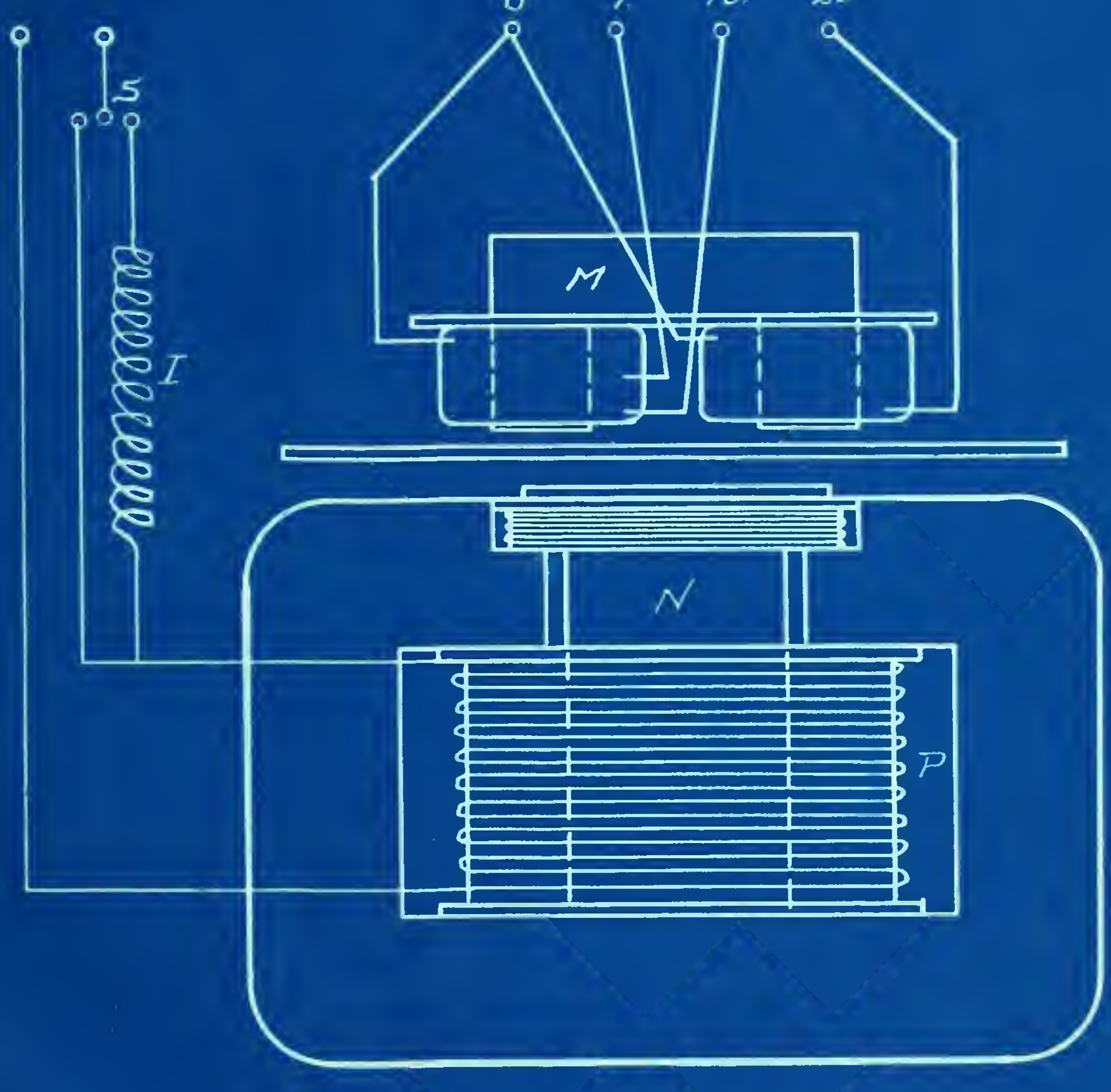


DIAGRAM
OF
THOMPSON TEST METER

THE APPARATUS USED IS AS FOLLOWS:

(0-5) Thompson, A.C., Ammeter. Type P, #115099.

(0-50) " " " " #51467.

(0-10) " " " " #140936

(0-100) " " " " #70511

(0-75) Weston A.C. and D.C. Voltmeter #753.
(0-150)
(0-25) " " " " " #3484

(0-150) Thompson " " " " #822.

(0-250) Weston " " " " #18993.

(80-140) Alternation, 110 volt. Hartman and Kempf frequency meter #205379, also meter #249193.

3000 Ampere current transformer, made at Armour Institute.

G.E. Current transformer #130069, Type S, normal load, 1300 amps., 30min. load 2000 amps., ratio, 80 to 1.

METHOD:

In carrying out these tests it was endeavored to reproduce actual operating conditions as nearly as possible. The voltage at the meter for any one run was kept constant at 100 volts. The load at meter was also kept constant during each run. The schme shown gives the connedtions of apparatus as used. Two 1" copper cables were connected to the secondary terminals of a series transformer. The ends of these cables were then bolted together forming a short cincuit for the secondary of the transformer. The primary terminals were connected thru an ammeter and a lamp bank to the terminals of an alternator. Leads were also ran out from the alternator terminals thru the wattmeter to be tested to a load consisting of incandescent lamps. An ammeter, and suitable rheostats for varying the voltage were placed in the circuit. A volt meter was placed across the terminals. From this description of the apparatus it is readily seen that the frequency of the current in the meter is the same as that causing the external field. It was thought that this was the best method, since in operating conditions the current in any cable near a meter is ussually of the same frequency as that in the meter itself.

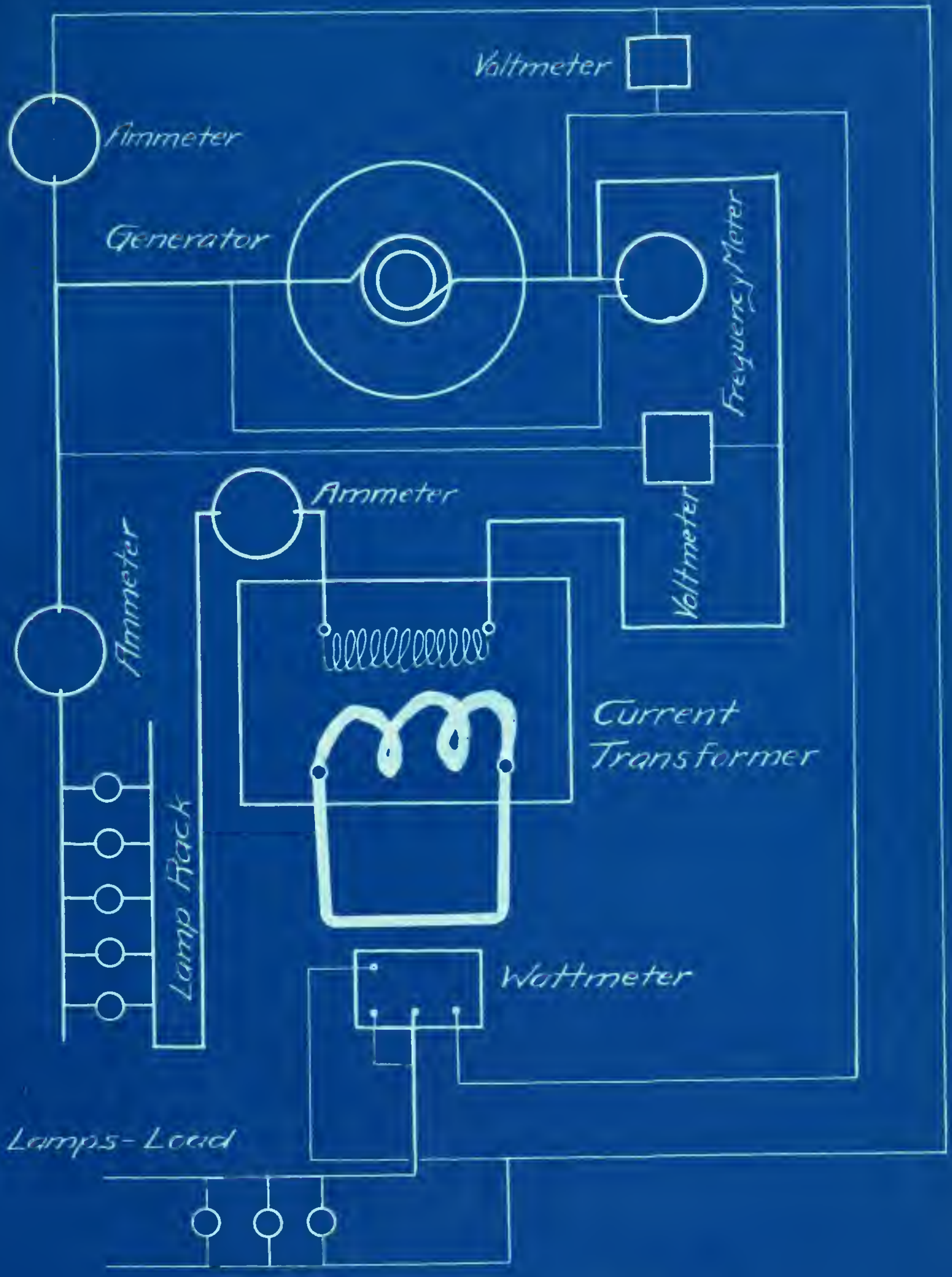
All of the meters tested were single phase. Three of them were of the induction type. The fourth was of the mercury cup type. These tests were made in the following

manner: The meter was opperated under two differnet loads; one at or near full load, and the other at from 20% to 40% full load. The wattmeter which was to be tested was first set up in its normal opperating position and the load put on. The large cable that short circuited the secondary of the current transformer was then brought near the meter(the exact position is given on the data sheets for each run) and the test was started. The disc of the meter was timed for a certain number of revolutions and the time recorded. Then a small load was put on the current transformer so that it would give from 200 to 600 amperes thru the short circuited secondary. The time of the same number of revolutions of the disc was then taken as before and recorded. In this way several readings were taken for each value of field current. On account of the very poor quality of the stop watches available some discrepancies are shown in the readings. However, in most cases, several readings were taken for each value of field current, and in this way better results were obtained

The cable was placed in various positions relative to the wattmeter. Readings were taken for each positions with two loads on the meter. Two curves were plotted as shown for each run. The abscissae show values of field current and the ordinates show revolutions per second in one case and per cent error in the other. The per cent error was figured out by assuming the zero field current

value as correct, and for any other value the difference between it and the zero current value divided by the zero current value times 100, was taken as the per cent error.

The current in the field cable, by which is meant the current in the cable producing the external field, was, found by multiplying the value of the primary current by the ratio of transformation (44:1) which was determined in the laboratory. The current transformer used was one that was made in the labortatory of the Institute. The value of the field was limited by the out-put of the alternator used. In making the various runs several machines had to be used in order to get the proper frequency and current. It would have been interesting to have been able to use higher values of field current had there been a means of so doing. The effects of a direct current field upon an alternating current meter would also be interesting to study. Tests might also be made using field currents of different frequencies from that of the meter current. These however, are beyond the scope of this thesis and are therefore not considered.



SCHEME OF CONNECTIONS

Discussion:-

The general effect of an external field upon the accuracy of the meters tested can easily be seen from the curves which are shown for each meter on the blue prints enclosed in this thesis. Beginning with the"Westinghouse" meter, we find there is only a small effect upon the meters accuracy for values of external field current as high as 1000 amperes. However, with an external field current of 2000 amperes we find that there is an error of four or five percent. With the cable in a vertical position the maximum error is less than with the cable in a horizontal position.

The Sangamo meter we find gives about four or five percent error, the same as the Westinghouse meter for heavy loads on the meter,and an error of about half this or about two percent.error for the smaller loads of abput two amperes.

Coming now to the Fort Wayne Meter we find this is greater effect upon the meter than upon either the Westinghouse or Sangamo Meter. The first run was made with the cover removed from the meter and with the cable horizontal and directly in front of meter. This we found to have a very great effect upon the accuracy of the meter, an external field of only 1500 amperes producing an error of 165 %. For this run a light load of 1.9 amperes was used.

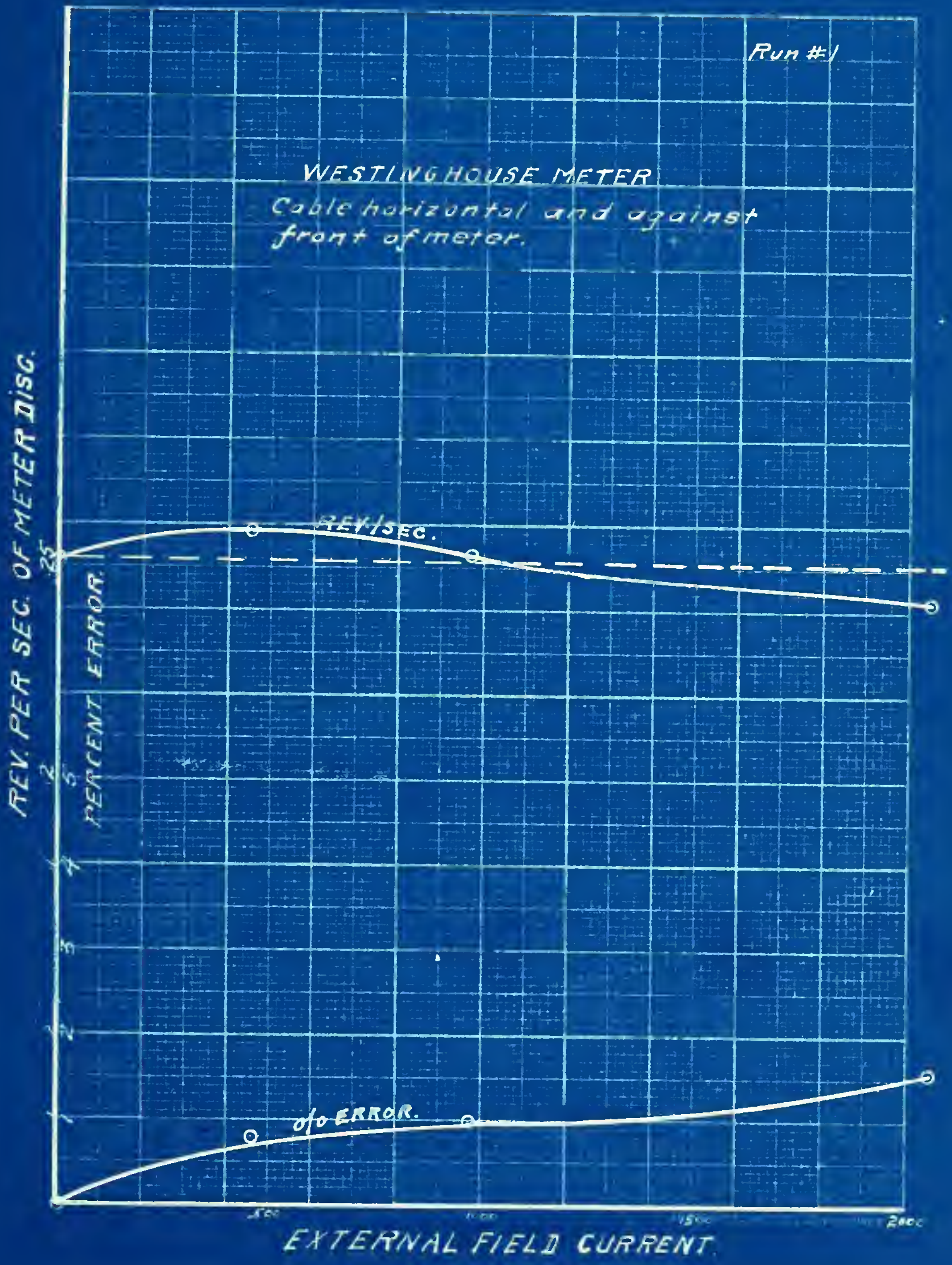
For the next run the cover was again placed on the meter, as this would be the actual running condition of the meter. It was thought best to make our tests under this condition. With the cover on the meter the error was reduced greatly for the same values of external field current. It is very evident that a Fort Wayne meter is easily effected by external fields. In one of our runs the cable was placed at a distance of one foot from the meter and even then the meter showed a very apprecialble error in the readings.

In some of the runs of this meter a very peculiar and inexplainable effect is noticeable. As the external field current is increased we get a corresponding increase in the error of the meter until the field current reaches a certain value. After this value has been reached the error of the meter begins to decrease with a further increase of field current. We have been unable to explain or get any information in regard to this effect.

The effect of an external filed current upon the Thompson Test Meter is also very marked as can be seen from our results. It would naturally be thought that a test meter would be even more accurate in all ways

than an ordinary recording meter for commercial use but from the curves shown it can be seen that if this meter were be used near conductors carrying a heavy current ther would in all probability be a considerable error in the readings of the meter. In the first run we get an error of about 95% with an external field current of 2000 amperes. Also in run #2 we get about the same amount of error with this same field current. With the cable at a distance of one inch from the meter we get an error of about six percent for an external field current of two thousand amperes, thus showing that the meter is very easily effected by an external field.

From the tests made on these meters it is very evident that to obtain accurate results with an alternating current meter it must not be used in the neighborhood of any disturbing fields. The effect on Westinghouse and Sangamo Meters is so small however, however that for all commercial purposes, these meters would not be appreciably effect.


Run #1
WESTINGHOUSE METER
Cable horizontal and against front of meter.
REV/SEC.
% ERROR.
REV. PER SEC. OF METER DISC.
PERCENT ERROR.
25
2
5
4
3
2
1
500
1000
1500
2000
EXTERNAL FIELD CURRENT

WESTINGHOUSE METER.

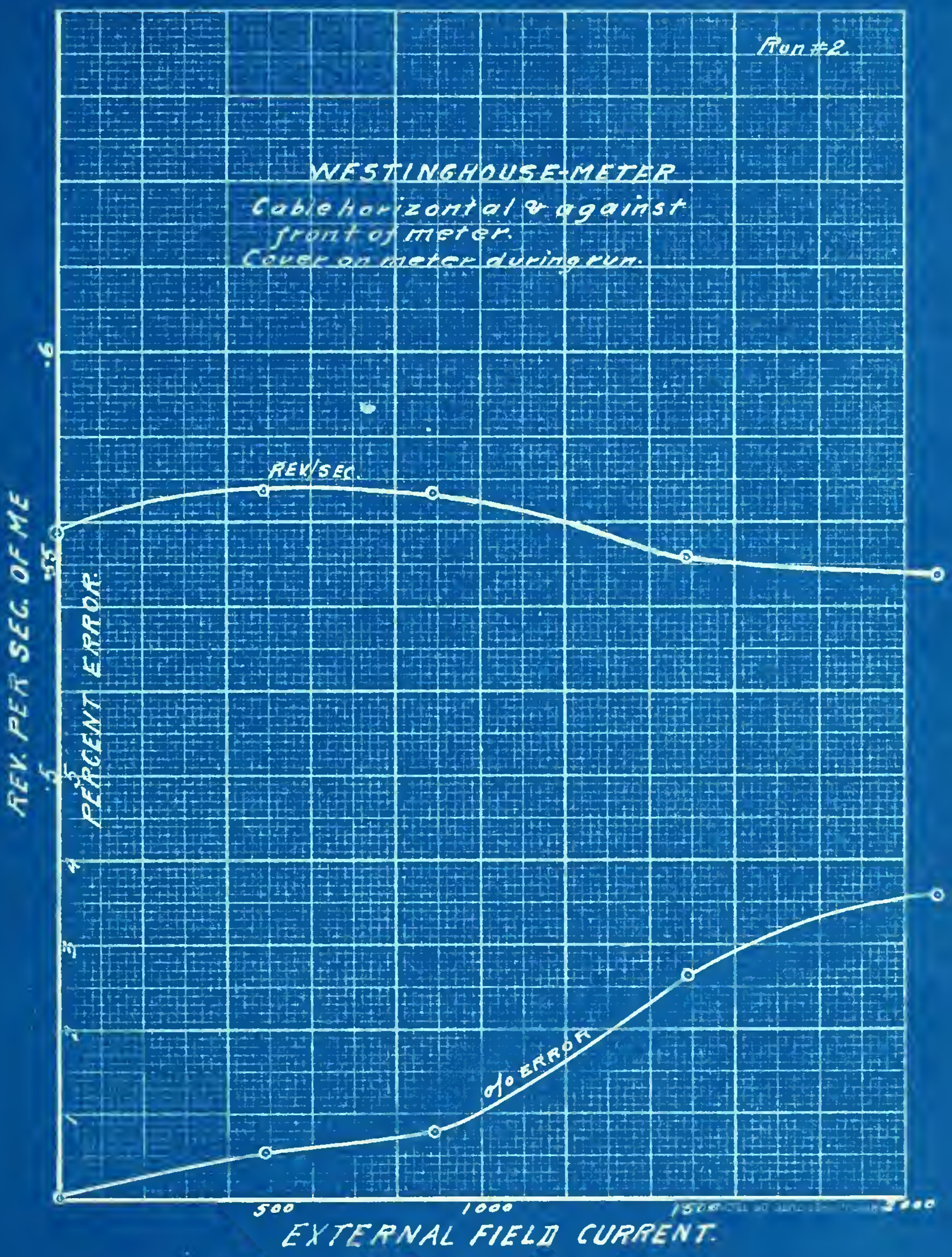
110 Volts. 5 Amperes. 60 Cycles.

#681372.

RUN #1

External Field Current. (Amps)	Load on Meter. (Amps)	Voltage on Meter.	Rev. of Meter Disc.	Time. (Sec)	Ave. Time.	Rev. per Sec.	%error.
0	1.92	100	13	51.2	51.2	.252	0
"	"	"	"	"			
"	"	"	"	"			
"	"	"	"	"			
"	"	"	"	"			
"	"	"	"	"			
440	1.92	100	13	50.3	50.28	.2583	1.78
"	"	"	"	50.3			
"	"	"	"	50.4			
"	"	"	"	50.2			
"	"	"	"	50.2			
968	1.92	100	13	51.1	51.3	.2530	1.95
"	"	"	"	51.4			
"	"	"	"	51.4			
2068	1.92	100	13	54.o	53.875	.2415	2.5
"	"	"	"	53.4			
"	"	"	"	54.1			
"							
"	"	"	"	54.o			

Cable horizontal and against front of glass case on meter.


Run #2.
WESTINGHOUSE-METER
Cable horizontal & against front of meter.
Cover on meter during run.
REV/SEC.
% ERROR
.6
.55
.5
5
4
3
2
1
REV. PER SEC. OF ME
PERCENT ERROR.
500
1000
1500
2000
EXTERNAL FIELD CURRENT.

WESTINGHOUSE METER.

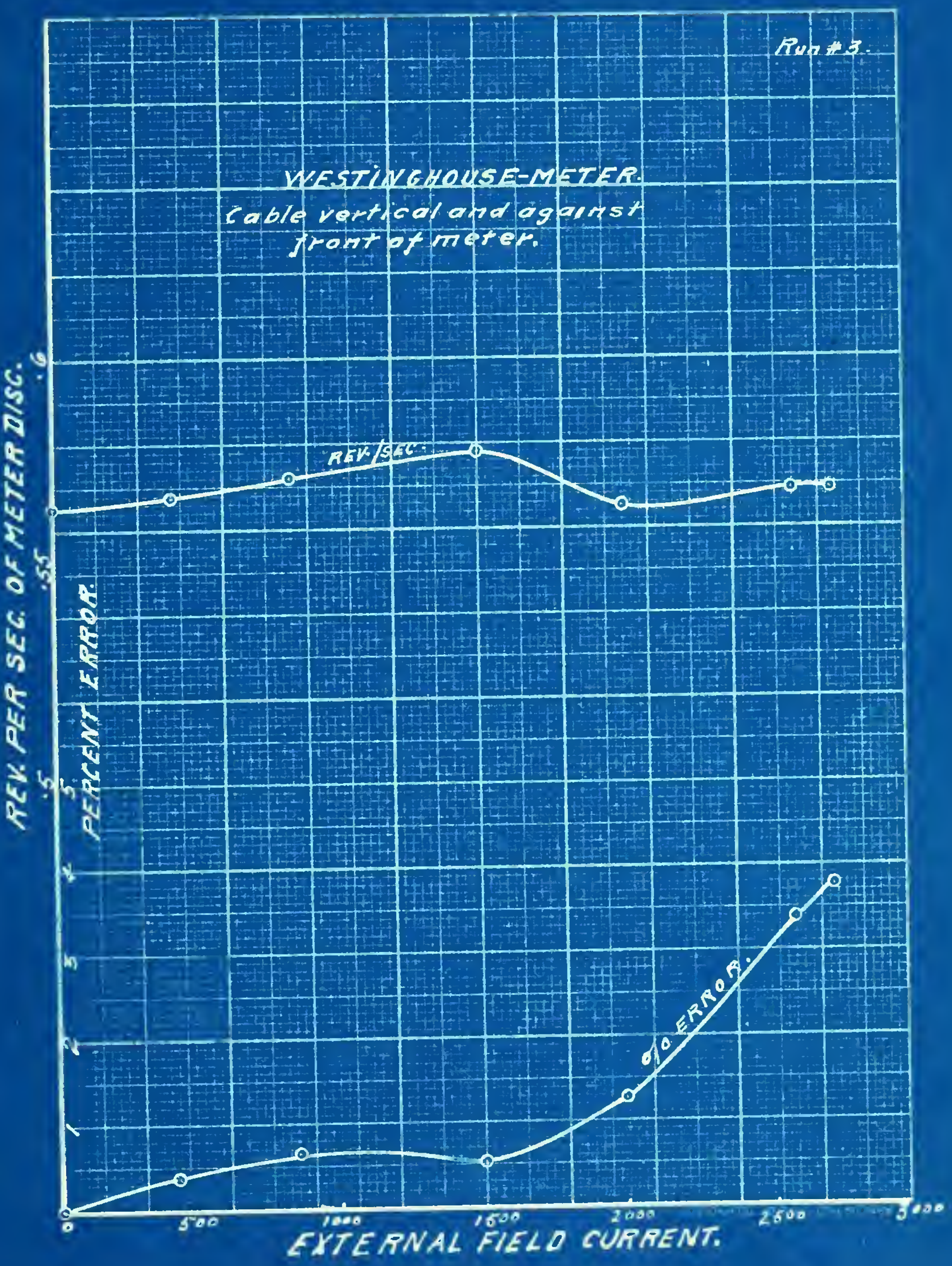
110 Volts. 5 Amperes. 60Cycles.

#681372.

RUN #2

External field Current.	Load on Meter.	Voltage on Meter.	Rev. of Meter Disc.	Time.	Ave. Time.	Rev. per Sec.	%error.
(Amps)	(Amps)			(sec)	(sec)		
0	4.5	100	30	53.0	52.9	.567	0
"	"	"	"	53.2			
"	"	"	"	52.8			
"	"	"	"	52.6			
484	4.5	100	30	52.6	52.733	.5675	.504
"	"	"	"	52.8			
"	"	"	"	52.8			
888.8	4.5	100	30	53	53.4	.562	.755
"	"	"	"	53.8			
"	"	"	"	53.4			
1487.2	4.5	100	30	54.4	54.4	.5515	2.64
"	"	"	"	54.4			
"	"	"	"	54.4			
2085.6	4.5	100	30	55	54.866	.5465	3.52
"	"	"	"	54.8			
"	"	"	"	54.8			

Cable horizontal and against front of glass on meter.


Run #3.
WESTINGHOUSE-METER.
Cable vertical and against
front of meter.
REV./SEC.
% ERROR.
REV. PER SEC. OF METER DISC.
.6
.55
.5
PERCENT ERROR.
5
4
3
2
1
0
500
1000
1500
2000
2500
3000
EXTERNAL FIELD CURRENT.

WESTINGHOUSE METER.

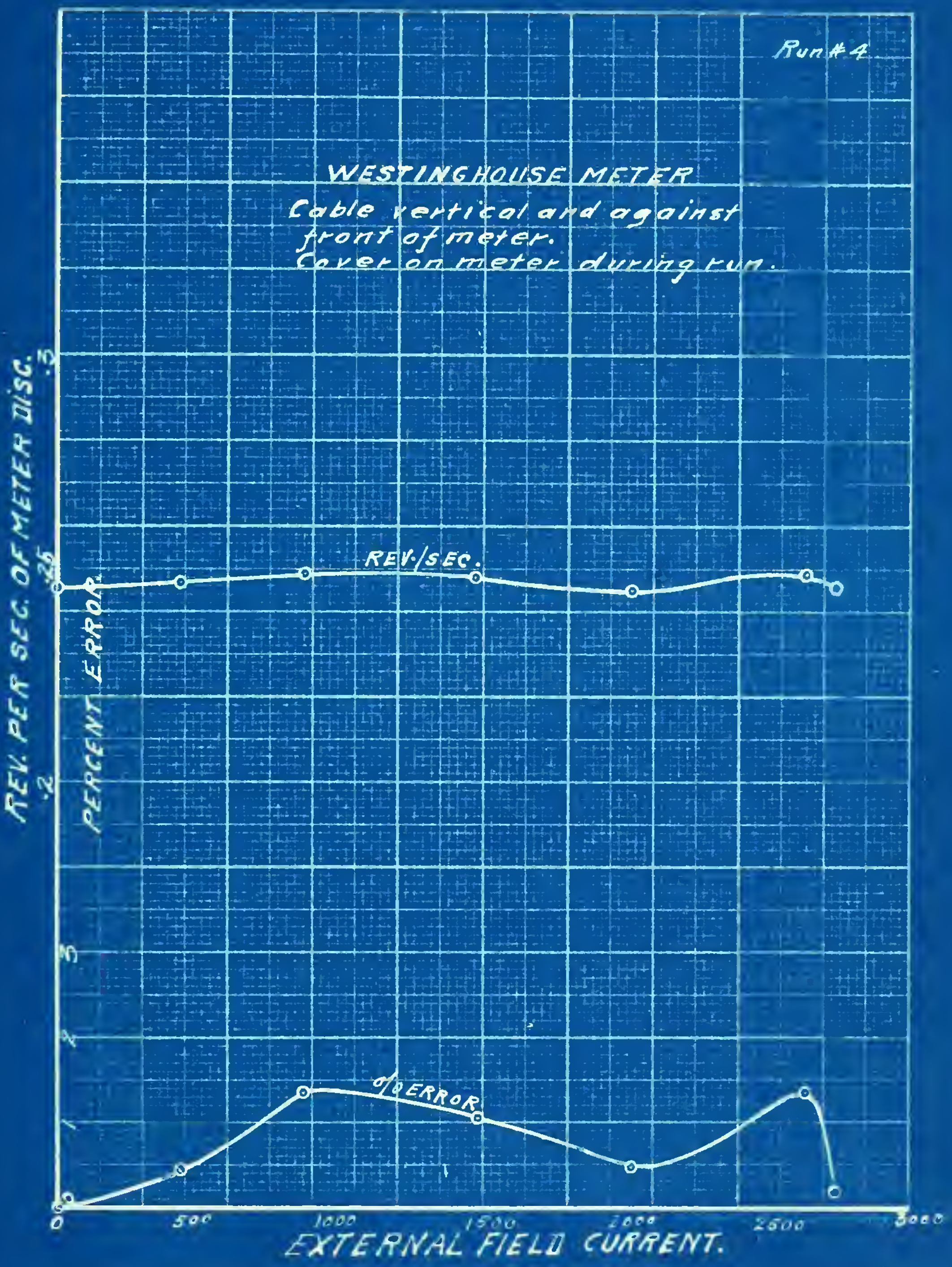
110 Volts. 5 Amperes. 60 Cycles.

#681372.

RUN #3

External feild Current. (Amps)	Load on Meter.	Voltage on Meter.	Rev. of Meter Disc.	Time.	Ave. Time.	Rev. per Sec.	%error.
0	4.5	100	30	53.2	53.066	.565	0
"	"	"	"	53.0			
"	"	"	"	53.0			
462	4.5	100	30	53.0	52.866	.5675	.376+
"	"	"	"	52.8			
"	"	"	"	52.8			
866.8	4.5	100	30	53.4	53.4	.562	.629
"	"	"	"	53.4			
1500.4	4.5	100	30	52.4	52.8	.568	.501
"	"	"	"	52.8			
"	"	"	"	53.0			
"	"	"	"	53.0			
2028.4	4.5	100	30	54.0	53.75	.558	1.289
"	"	"	"	53.6			
"	2	"	"	53.6			
"	"	"	"	53.8			
2596	4.5	100	30	51.4	51.266	.585	3.39
"	"	"	"	51.2			
"	"	"	"	51.2			
2697.2	4.5	100	30	51.4	51.066	.587	3.77
"	"	"	"	51.0			
"	"	"	"	50.8			

Cable vertical and against front of glass case on meter.


Run #4
WESTINGHOUSE METER
Cable vertical and against
front of meter.
Cover on meter during run.
REV./SEC.
% ERROR
REV. PER SEC. OF METER DISC.
PERCENT ERROR
.3
.25
.2
3
2
1
0
500
1000
1500
2000
2500
3000
EXTERNAL FIELD CURRENT.

WESTINGHOUSE METER.

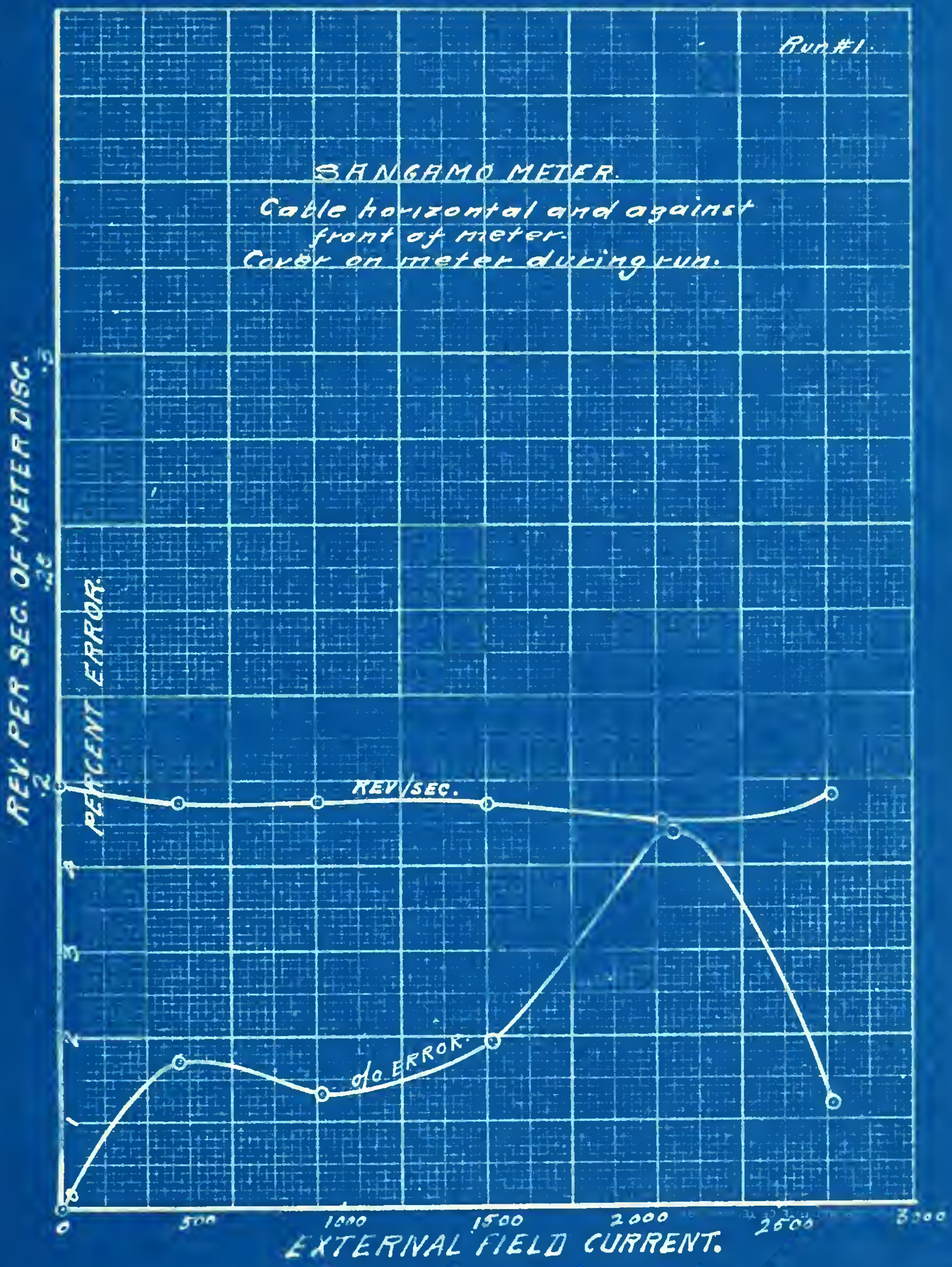
110 Volts. 5 Amperes. 60 Cycles.

#681372.

RUN #4

External field Current. (Amps)	Load on Meter. (Amps)	Voltage on Meter.	Rev. of Meter Disc.	Time.	Ave. Time.	Rev. per sec.	%error.
0	1.88	100	13	52.8	52.93	.2458	0
"	"	"	"	53.0			
"	"	"	"	53.0			
485	1.88	100	13	52.4	52.70	.247	.435
"	"	"	"	53.0			
"	"	"	"	53.0			
"	"	"	"	52.4			
912	1.88	100	13	52.4	52.2	.249	1.38
"	"	"	"	52.0			
"	"	"	"	52.2			
1490	1.88	100	13	52.4	52.4	.248	1.001
"	"	"	"	52.6			
"	"	"	"	52.2			
2450	1.88	100	13	53.2	53.13	.245	.38
"	"	"	"	53.2			
"	"	"	"	53.2			
2595	1.88	100	13	51.8	52.2	.249	1.38
"	"	"	" "	52.6			
"	"	"	"	52.2			
"	"	"	"	52.2			
2700	1.88	100	13	52.8	52.8	.2462	.13

Cable vertical and against front of glass case on meter.



Run #1.

SANGAMO METER.

Cable horizontal and against front of meter.
Cover on meter during run.

SANGAMO METER.

110 Volts. 10 Amperes. Cycles-Any.

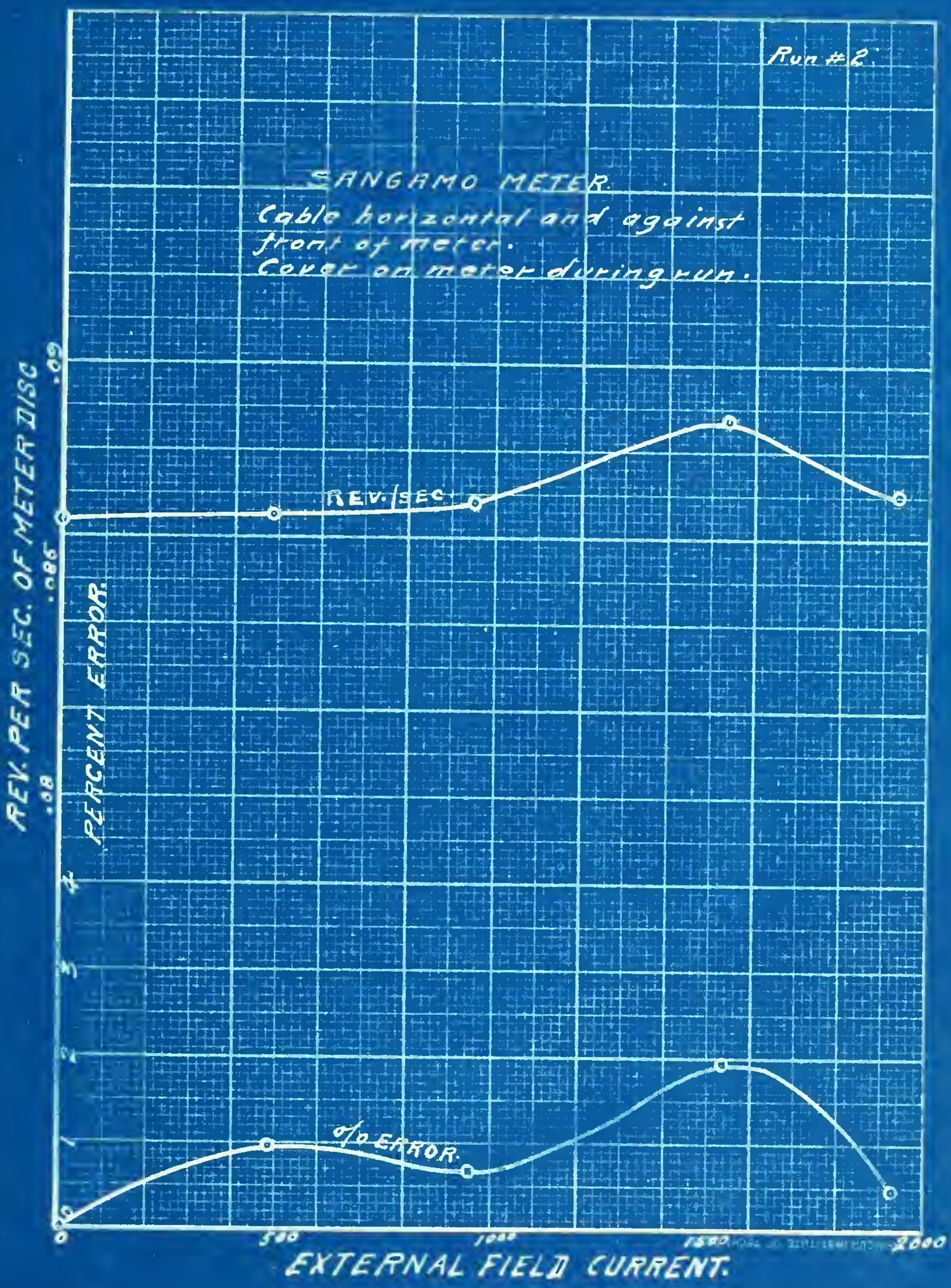
#66151.

RUN #1

External field Current. (Amps)	Load on Meter. (Amps)	Voltage on Meter.	Rev. of Meter Disc.	Time. (sec)	Ave. Time. (sec)	Rev. per Sec.	% error.
0	4.5	100	10	50.4	50.4	.1985	0
"	"	"	"	50.4			
0	4.5	100	10	51..4	51.266	.195	1.719
"	"	"	"	51.2			
"	"	"	"	51.2			
906.4	4.5	100	10	50.8	51.066	.1959	1.32
"	"	"	"	51.2			
"	"	"	"	51.2			
1518	4.5	100	10	51.4	51.4	.1946	1.982
"	"	"	"	51.4			
2112	4.5	100	10	52.4	52.666	.19	4.5
"	"	"	"	, 52.8			
"	"	"	"	52.8			
2684	4.5	100	10	51	51	.196	1.19
"	"	"	"	51			
"	"	"	"	51			

Cable horizontal and against glass case on front of meter.

60 Cycles used for run.


Run #2.
SANGAMO METER.
Cable horizontal and against
front of meter.
Cover on meter during run.
REV. PER SEC. OF METER DISC
.08
.085
.09
PERCENT ERROR.
0
1
2
3
4
REV./SEC.
%ERROR.
0
500
1000
1500
2000
EXTERNAL FIELD CURRENT.

SANGAMO METER.

110 Volts. 10 Amperes. Cycles-Any.

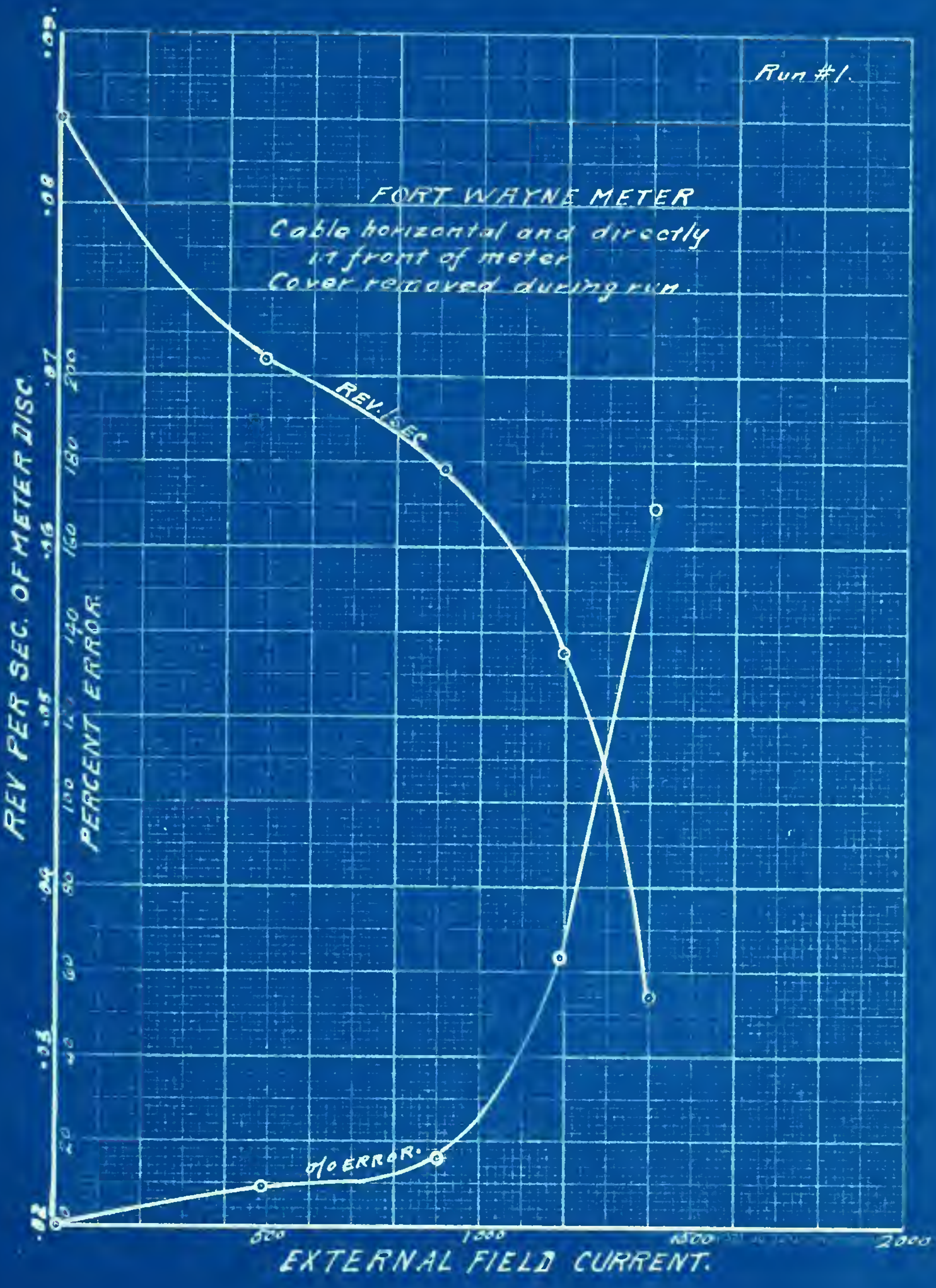
#66151.

RUN #2.

External field Current. (Amps)	Load on Meter. (Amps)	Voltage on Meter.	Rev. of Meter Disc.	Time. (sec)	Ave. Time. (Sec)	Rev. per Sec.	%error.
0	2	100	5	58.4	57.933	.0864	0
"	"	"	"	57.2			
"	"	"	"	58.2			
484	2	100	5	58.6	58.5	.0855	.98
"	"	"	"	58.4			
950.4	2	100	5	58.4	58.3	.0858	.634
"	"	"	"	58.2			
1540	2	100	5	56.8	56.8	.0880	1.959
"	"	"	"	56.8			
1936	2	100	5	58.2	58.2	.0860	.461
"	"	"	"	58.2			

Cable horizontal and against front of glass case on meter.

60 Cycles used for run.

Run #1.
FORT WAYNE METER
Cable horizontal and directly in front of meter
Cover removed during run.
REV./SEC.
% ERROR.
REV PER SEC. OF METER DISC.
PERCENT ERROR.
.02
.03
.04
.05
.06
.07
.08
.09
0
20
40
60
80
100
120
140
160
180
200
500
1000
1500
2000
EXTERNAL FIELD CURRENT.

FORT WAYNE METER.

100 Volts. 10 Amperes. Cycles 125-140.

#65181.

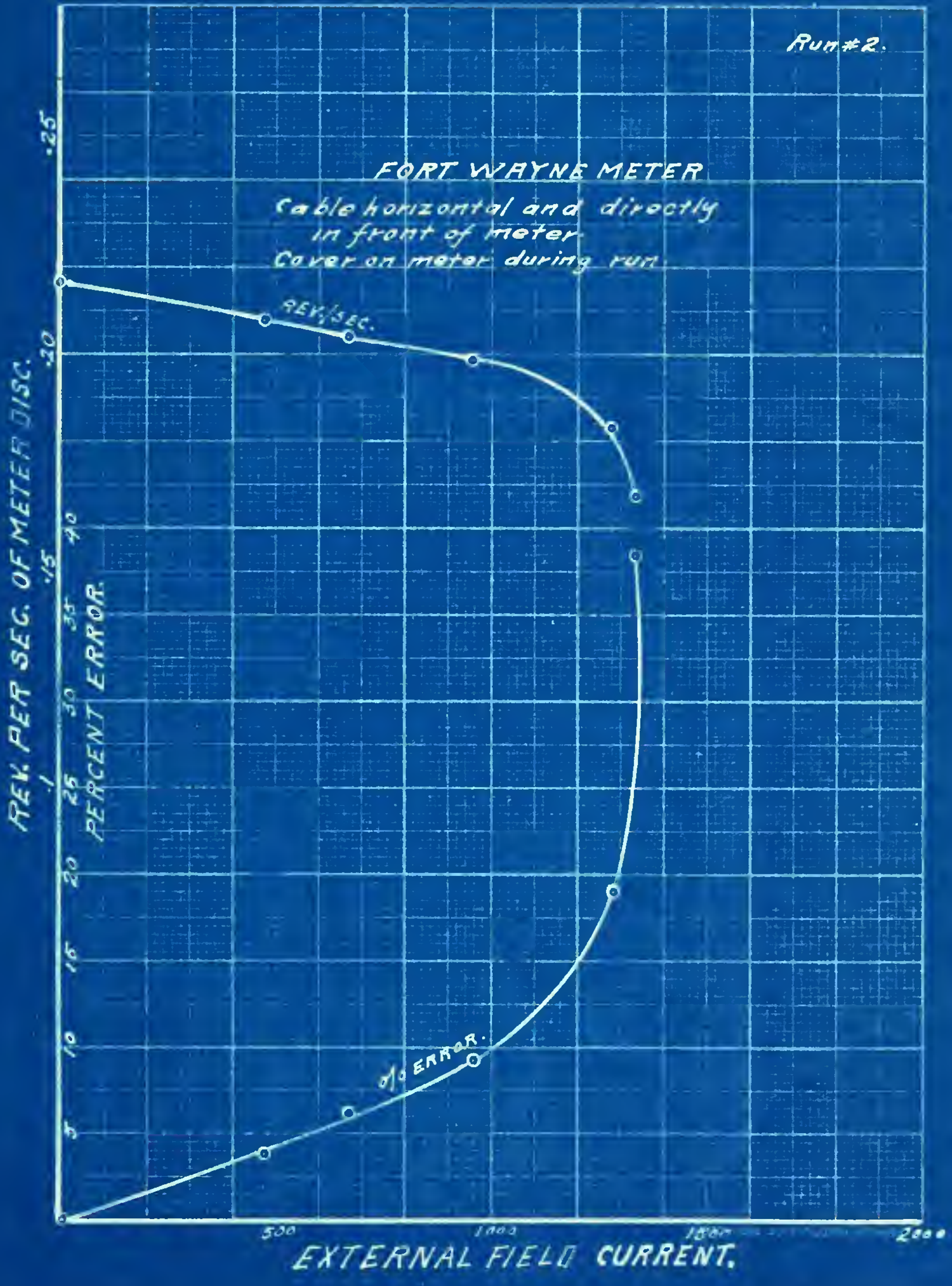
RUN #1

External field Current. (amps)	Load on Meter. (amps)	Voltage on Meter.	Rev. of Meter Disc.	Time. (sec)	Ave. Time. (sec)	Rev. per sec.	%error.
0	1.9	100	5	58.6	58.93	.085	0
"	"	"	"	59.0			
"	"	"	"	59.2			
484	1.9	100	5	68.2	70.35	.071	19.43
"	"	"	"	68.8			
"	"	"	"	72.2			
"	"	"	"	72.2			
902	1.9	100	5	82.0	77.67	.0645	31.90
"	"	"	"	76.0			
"	"	"	"	75.0			
1190	1.9	100	5	99.0	96.33	.0536	63.50
"	"	"	"	95.0			
"	"	"	"	95.0			
1308	1.9	100	5	140.6	149.6	.0335	168.5
"	"	"	"	158.6			

Cable horizontal and directly in front of meter.

Cover removed from meter during run.

135 Cycles used during run.



FORT WAYNE METER

Cable horizontal and directly
in front of meter.
Cover on meter during run.

FORT WAYNE METER.

100 Volts   10 Amperes.   Cycles 125-140

#65181.

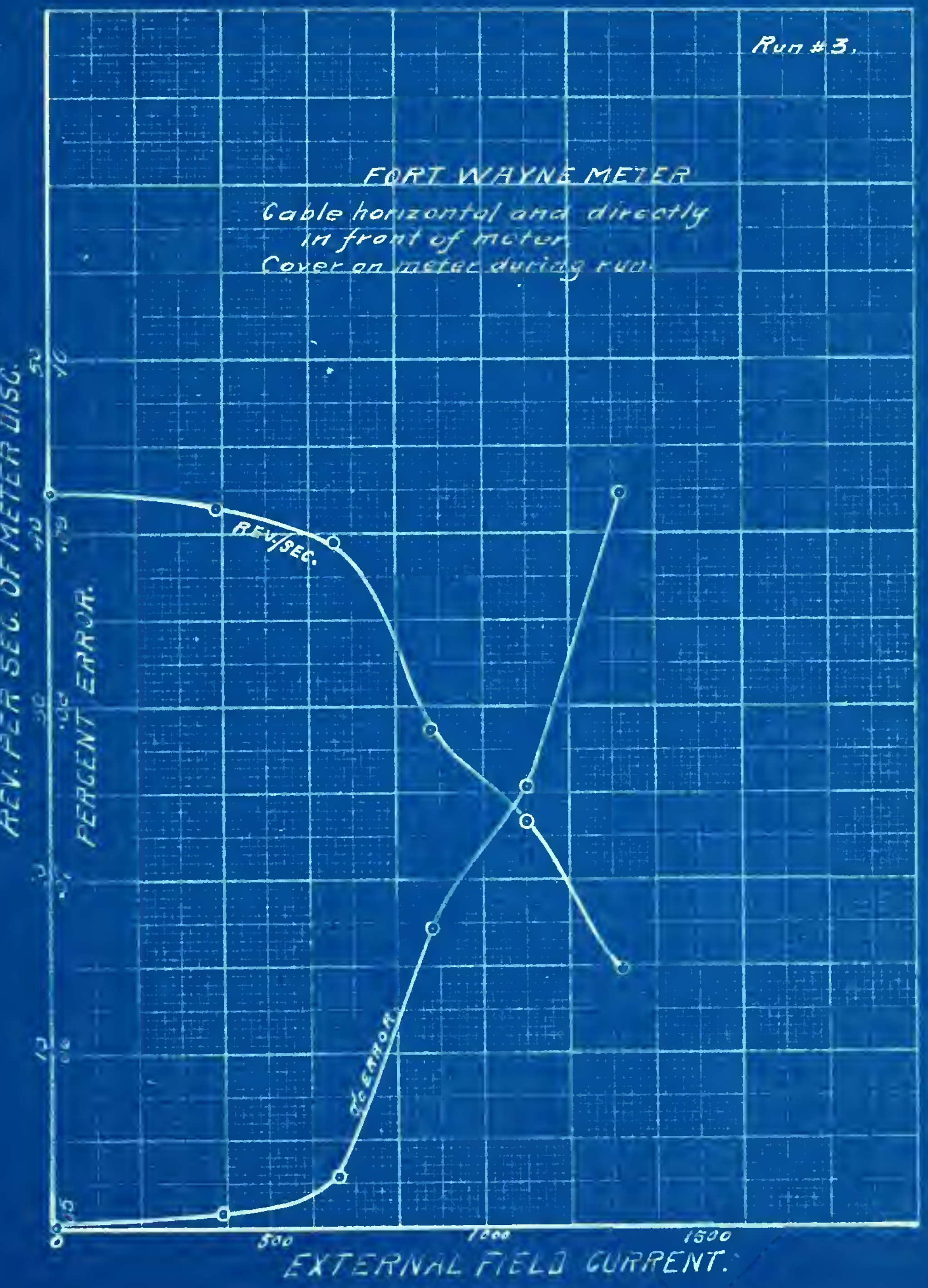
RUN #2

External field Current. (amps)	Load on Meter. (Amps)	Voltage on Meter.	Rev.of Meter Disc.	Time. (Sec)	Ave. Time. (Sec)	Rev. per Sec.	%error.
0	4.5	100	10	46.2	46.2	.2161	0
"	"	"	"	46.2			
470.8	4.5	100	10	47.4	48.0	.208	3.9
"	"	"	"	48.2			
"	"	"	"	48.4			
664.4	4.5	106	10	49.0	49.0	.204	6.06
"	"	"	"	49.0			
959.2	4.5	100	10	51.0	50.33	.1989	8.94
"	"	"	"	50.0			
"	"	"	"	50.0			
1333.2	4.5	100	10	64.0	64.0	.1563	38.

Cable horizontal and directly in front of meter.

Cover on meter during run.

135 Cycles used during run.

Run #3.
FORT WAYNE METER
Cable horizontal and directly in front of meter.
Cover on meter during run.
REV. PER SEC. OF METER DISC.
PERCENT ERROR.
50
10
40
30
20
10
5
0
500
1000
1500
EXTERNAL FIELD CURRENT.
REV./SEC.
% ERROR.

FORT WAYNE METER.

100 Volts. 10 Amperes. Cycles 125-140.

#65181.

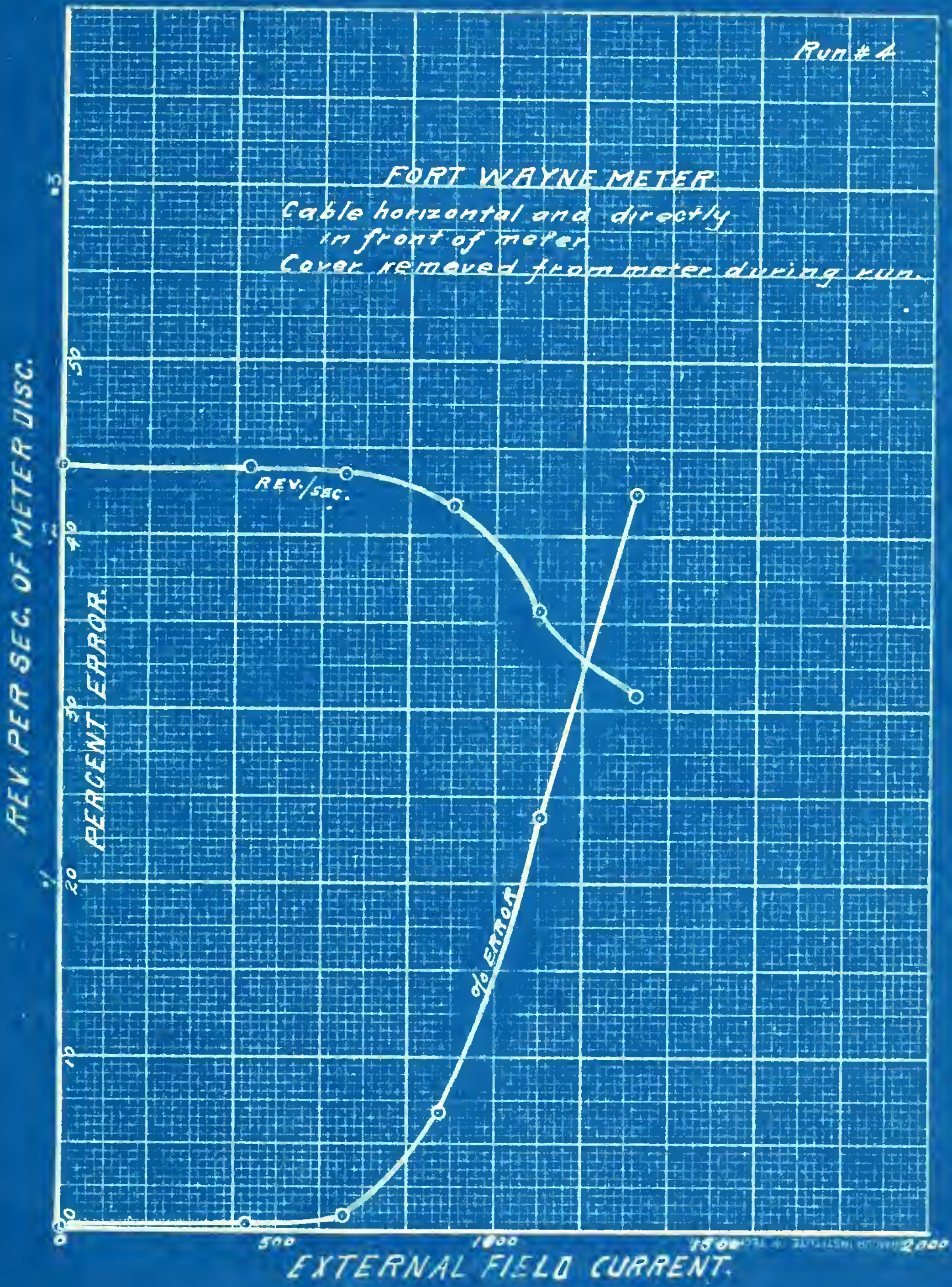
RUN #3.

External field Current. (amps)	Load on Meter. (amps)	Voltage on Meter.	Rev. of Meter Disc.	Time. (Sec)	Ave. Time. Sec)	Rev. per sec.	%error.
0	1.9	100	5	53.6	54.266	.0922	0
"	"	"	"	54.4			
"	"	"	"	54.8			
396	1.9	100	5	54.2	54.666	.0915	.757
"	"	"	"	55.8			
"	"	"	"	54.0			
660	1.9	100	5	55.8	55.8	.0896	2.83
"	"	"	"	55.8			
880	1.9	100	5	63.6	63.6	.0786	17.2
"	"	"	"	63.6			
1100	1.9	100	5	69.2	68.2	.0734	25.35
"	"	"	"	67.2			
1320	1.9	100	5	77.2	77.2	.0648	42.25
"	"	"	"	77.2			

Cable horizontal and directly in front of meter.

Cover on meter during run.

135 Cycles used during run.


Run # 4
FORT WAYNE METER
Cable horizontal and directly in front of meter.
Cover removed from meter during run.
REV./SEC.
% ERROR
REV. PER SEC. OF METER DISC.
PERCENT ERROR.
.3
.2
.1
0
50
40
30
20
10
0
0
500
1000
1500
2000
EXTERNAL FIELD CURRENT.

FORT WAYNE METER.

100 Volts. 10 Amperes. Cycles 125-140

#65181.

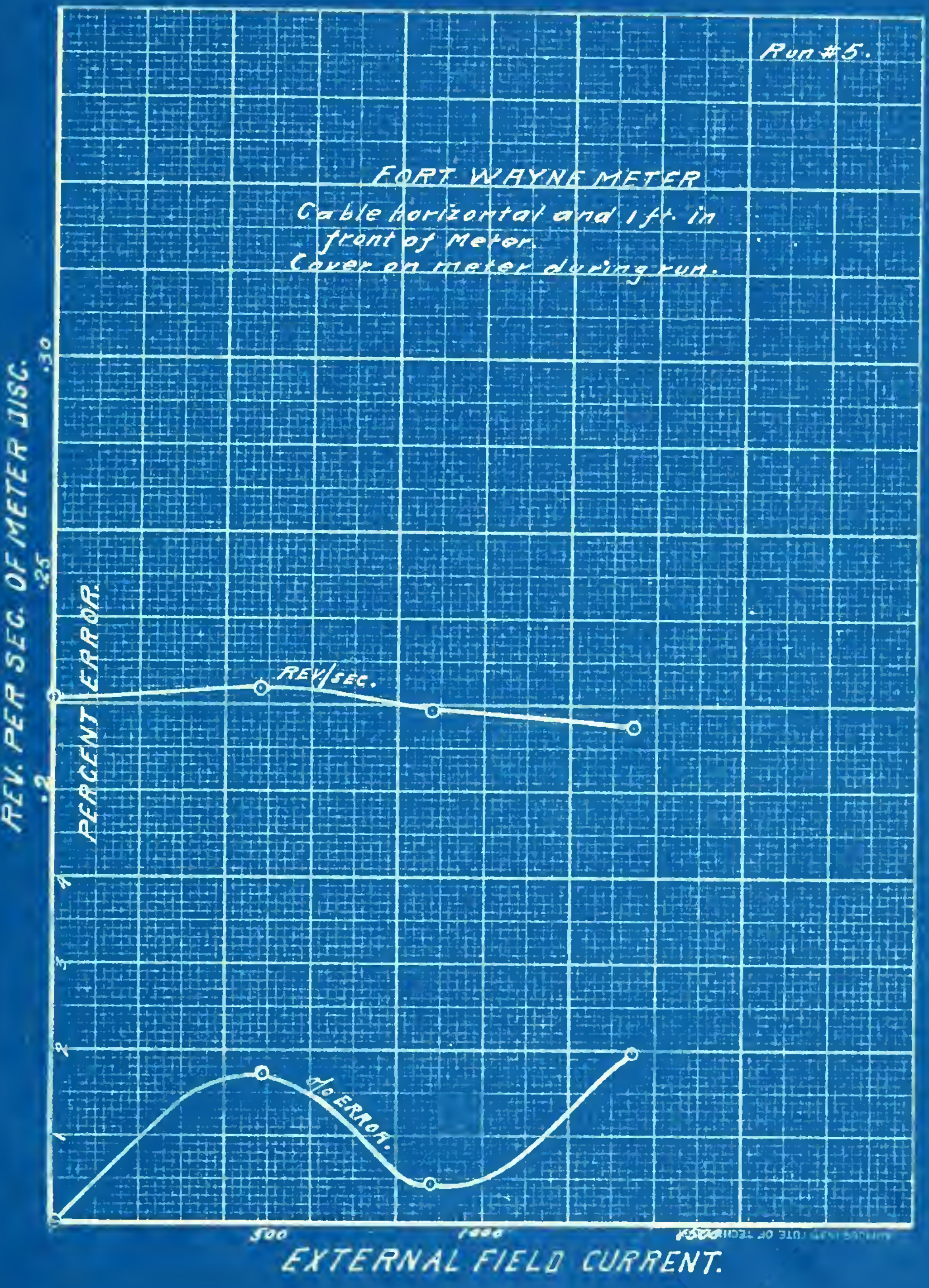
RUN #4

External field Current. (Amps)	Load on Meter. (Amps)	Voltage on Meter.	Rev. of Meter Disc.	Time. (Sec)	Ave. Time. (Sec)	Rev. per Sec.	%error.
0	4.5	100	10	45.4	45.4	.22	0
"	"	"	"	45.4			
426.8	4.5	100	10	45.6	45.5	.22	.22
"	"	"	"	45.4			
655.6	4.5	100	10	45.5	45.75	.219	.771
"	"	"	"	46.0			
866.8	4.5	100	10	47.4	48.0	.208	5.73
"	"	"	"	48.6			
1104.4	4.5	100	10	55.8	56.1	.1788	23.6
"	"	"	"	56.4			
1320	4.5	100	10	64.6	64.6	.1549	42.3

Cable horizontal and directly in front of meter.

Cover removed from meter during run.

135 Cycles used during run.



Run #5.

FORT WAYNE METER

Cable horizontal and 1 ft. in front of Meter.

Cover on meter during run.

FORT WAYNE METER.

100 Volts. 10 Amperes. Cycles 125-140

#65181.

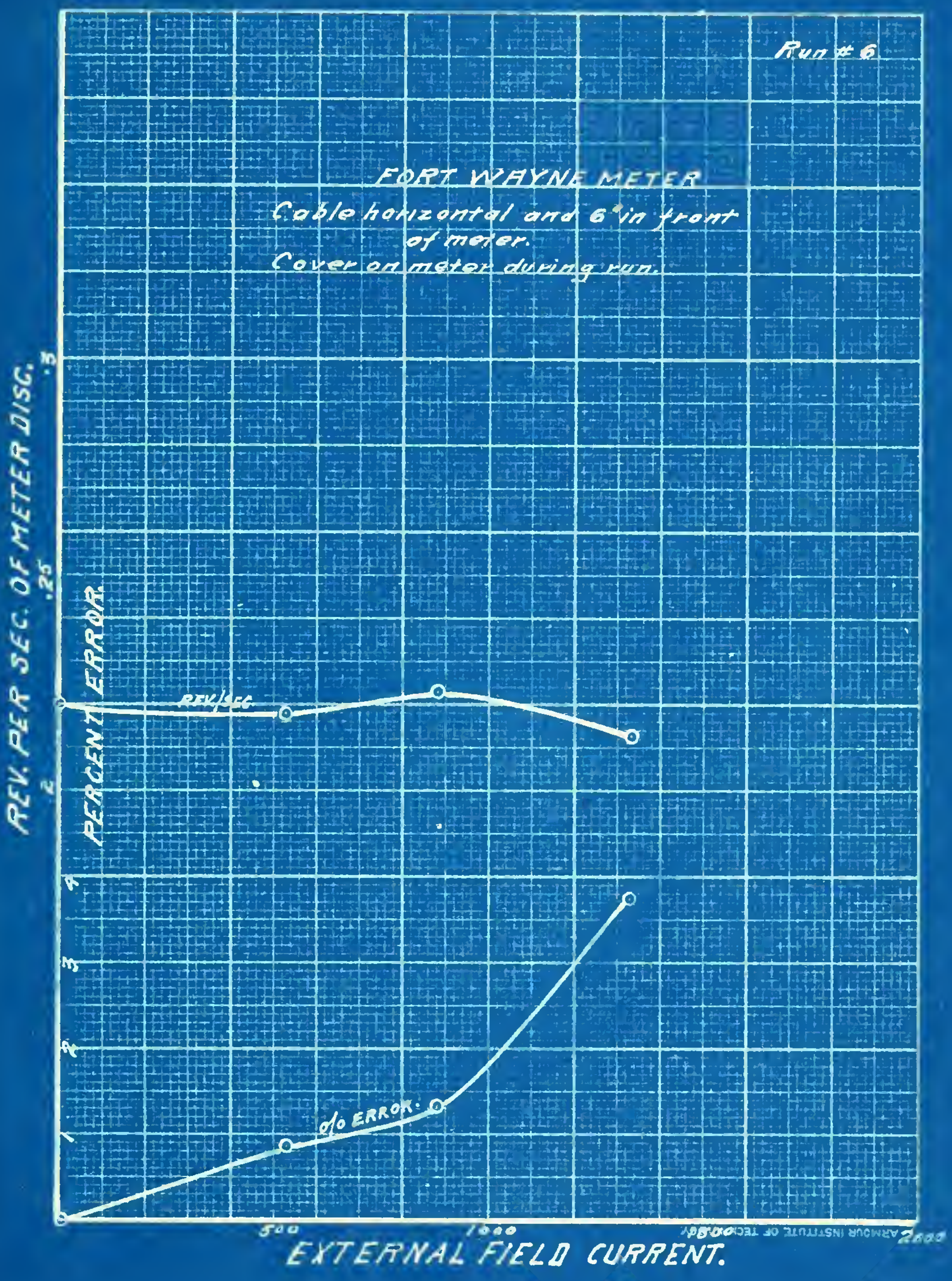
RUN # 5

External field Current. (amps)	Load on Meter. (amps)	Voltage on Meter.	Rev. of Meter Disc.	Time.)Sec)	Ave. Time. (sec)	Rev. per Sec.	%error.
0	4.5	100	10	45.4	45.4	.222	0
484	4.5	100	10	44.6	44.6	.224	1.76
880	4.5	100	10	45.6	45.6	.219	.44
1342	4.5	100	10	46.4	46.3	.215	1.98
"	"	"	"	46.2			

Cable horizontal and one foot in front of meter.

Cover on meter during run.

135 Cycles used during run.



Run # 6

FORT WAYNE METER

Cable horizontal and 6" in front of meter.

Cover on meter during run.

FORT WAYNE METER.

100 Volts. 10 Amperes. Cycles 125-140

#65181.

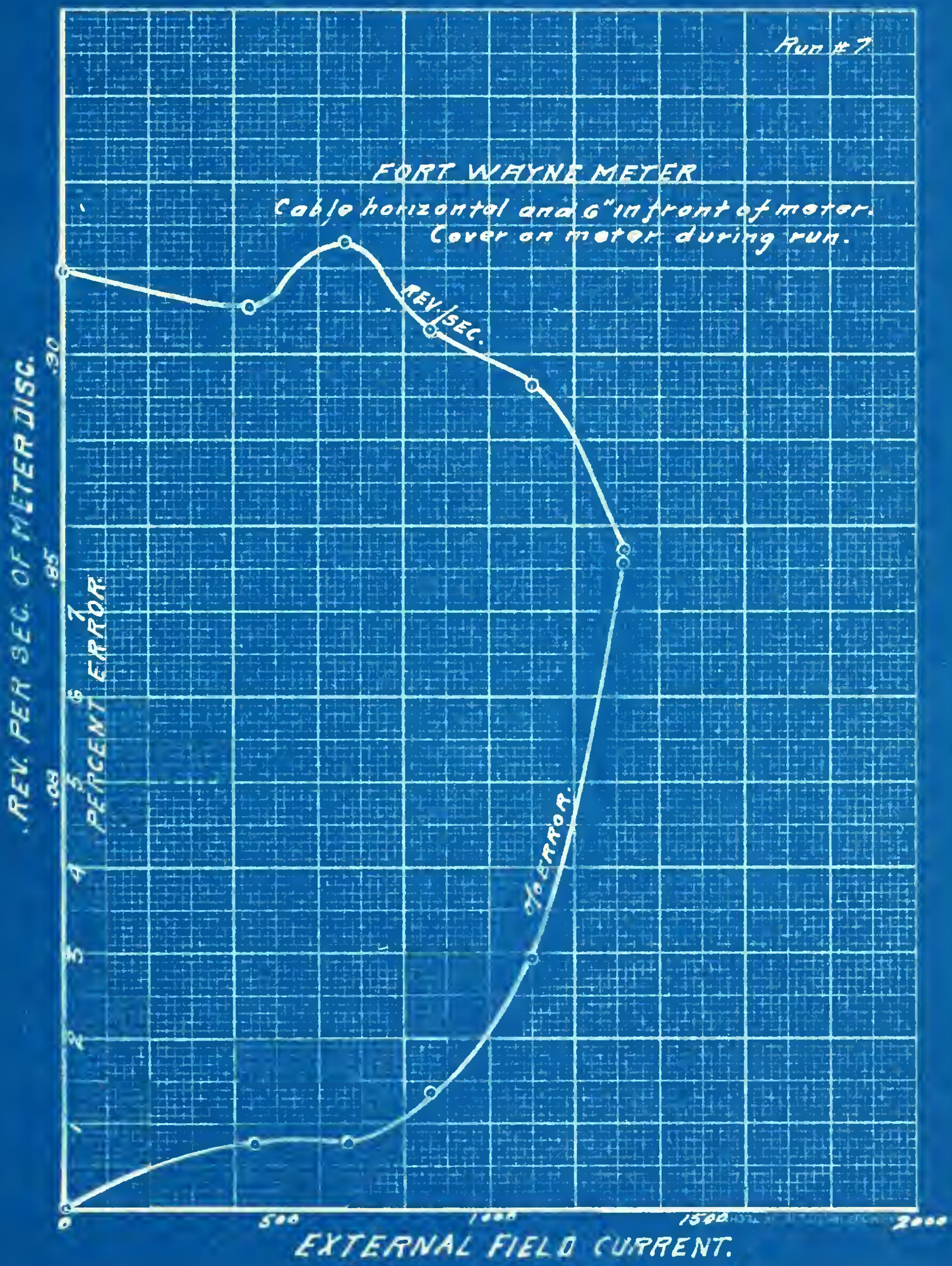
RUN #6.

External field Current. (amps)	Load on Meter. (amps)	Voltage on Meter.	Rev. of Meter Disc.	Time. (sec)	Ave. Time. (sec)	Rev. per sec.	%error.
0	4.5	100	10	45.4	45.4	.22	0
528	4.5	100	10	45.8	45.8	.218	.881
893.2	4.5	100	10	45.0	45.8	.223	1.32
"	"	"	"	44.6			
1328.8	4.5	100	10	47.2	47.1	.2122	3.75
"	"	"	"	47.0			

Cable horizontal and six inches in front of meter.

Cover on meter during run.

135 Cycles used during run.



Run # 7

FORT WAYNE METER

Cable horizontal and 6" in front of meter.
Cover on meter during run.

FORT WAYNE METER.

100 Volts. 10 Amperes. Cycles 125-140

#65181.

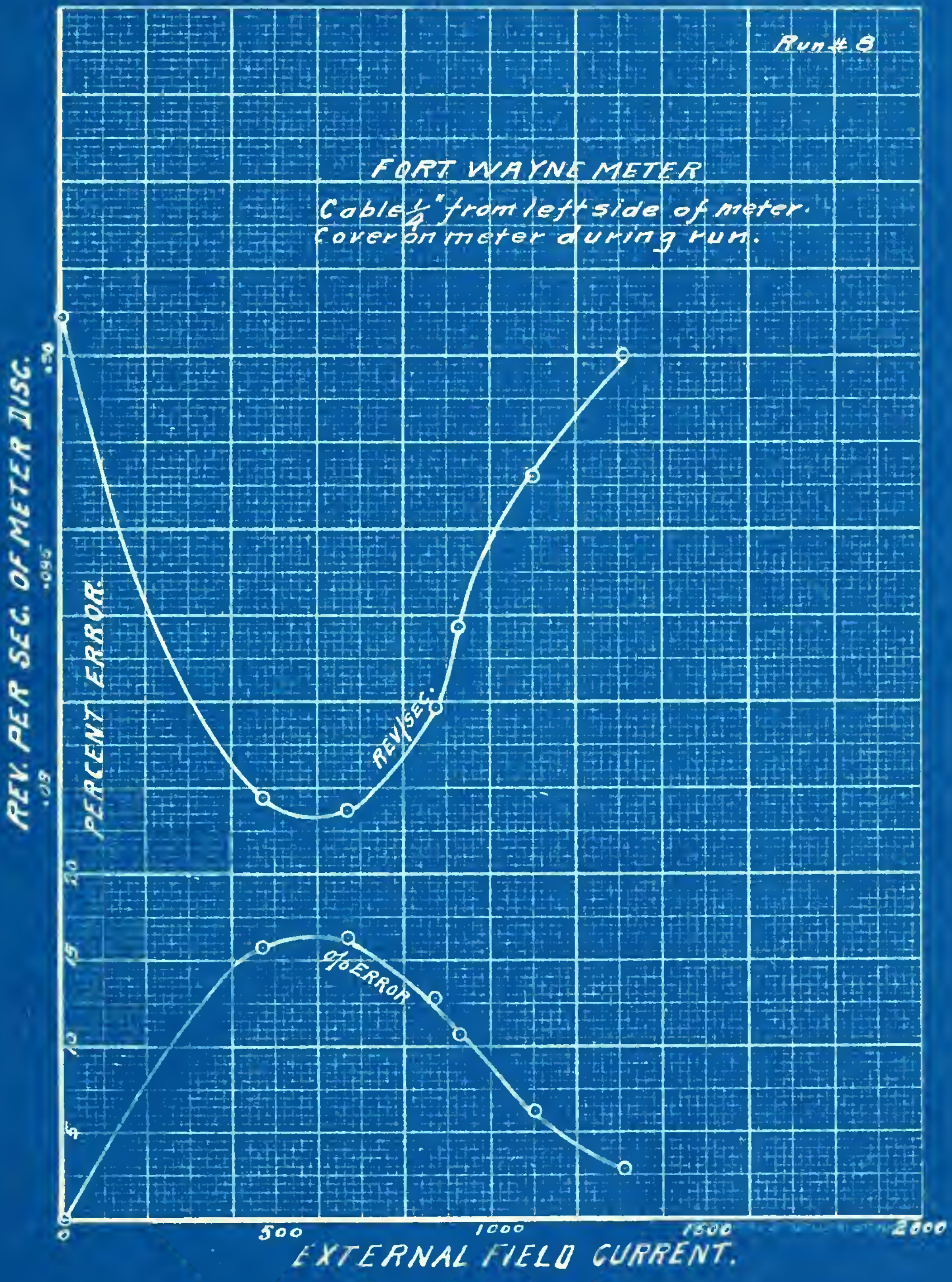
RUN #7

External field Current. (amps)	Load on Meter. (amps)	Voltage on Meter.	Rev. of Meter Disc.	Time. (sec)	Ave. Time. (sec)	Rev. per sec.	%error. %error.
0	1.9	100	5	54.4	54.4	.092	0
440	1.9	100	5	54.8	54.8	.0911	.725
"	"	"	"	54.8			
663	1.9	100	5	54.0	54.0	.0926	.725
"	"	"	"	54.0			
858	1.9	100	5	55.0	55.15	.0906	1.38
"	"	"	"	55.3			
1100	1.9	100	5	55.8	56.0	.0893	2.94
"	"	"	"	56.2			
1320	1.9	100	5	58.8	58.6	.0853	7.71
"	"	"	"	58.4			

Cable horizontal and six inches in front of meter.

Cover on meter during run.

135 Cycles used during run.


Run # 8
FORT WAYNE METER
Cable 1/4" from left side of meter.
Cover on meter during run.
REV/SEC.
% ERROR
REV. PER SEC. OF METER DISC.
PERCENT ERROR.
.10
.095
.09
20
15
10
5
0
500
1000
1500
2000
EXTERNAL FIELD CURRENT.

FORT WAYNE METER.

100 Volts. 10 Amperes. Cycles 125-140

#65181

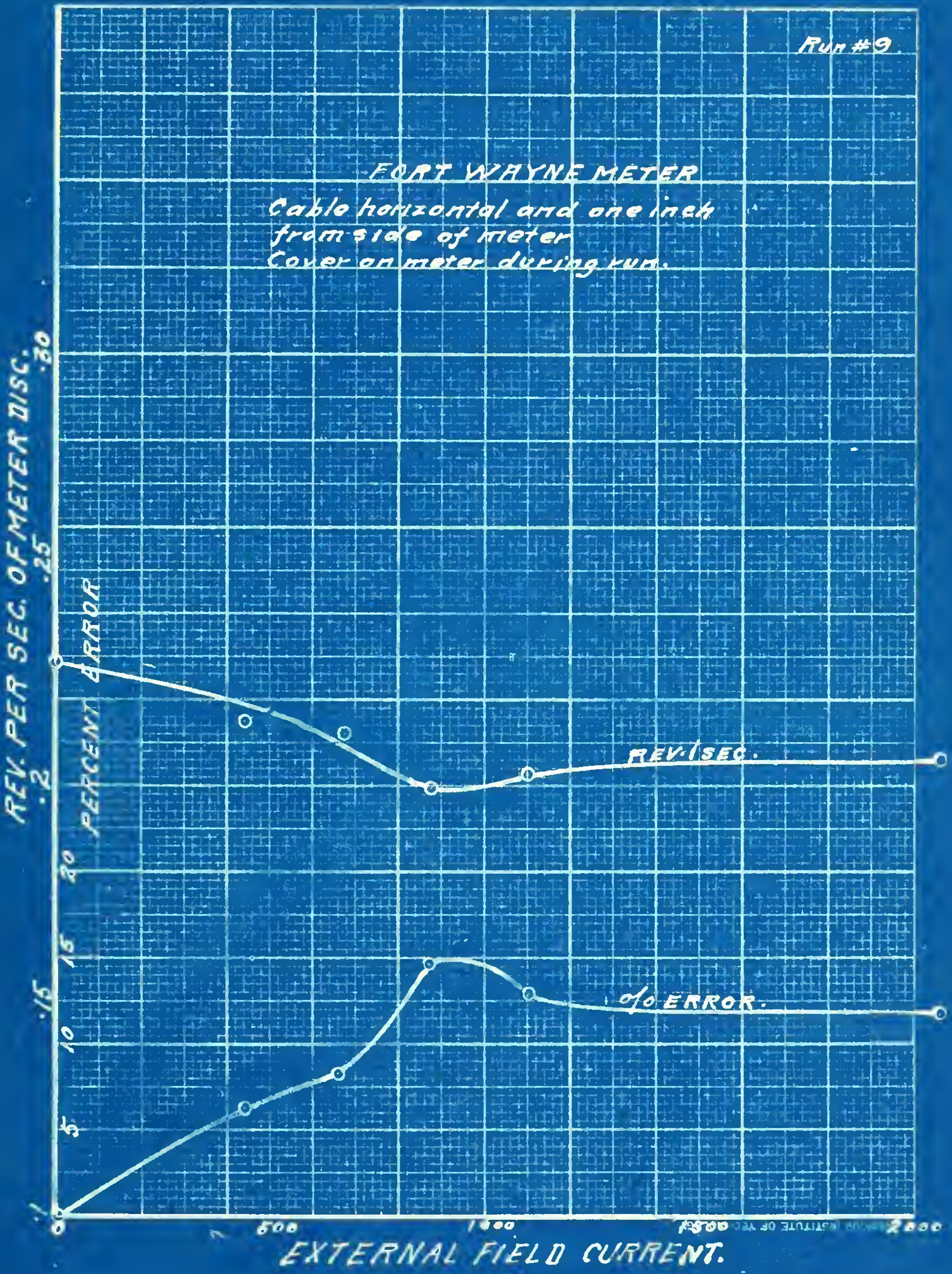
RUN # 8

External field Current. (amps)	Load on Meter. (amps)	Voltage on Meter.	Rev. of Meter Disc.	Time. (sec)	Ave. Time. (sec)	Rev. per Sec.	%error.
0	1.9	100	5	54.0	54.0	.0909	0
466.4	1.9	100	5	62.4	62.6	.0798	15.9
"	"	"	"	62.8			
668.8	1.9	100	5	62.4	62.9	.0795	16.46
"	"	"	"	63.4			
871.2	1.9	100	5	61.0	61.0	.0819	12.95
"	"	"	"	61.0			
"	"	"	"	61.0			
924	1.9	100	5	59.6	59.7	.0837	10.55
"	"	"	"	59.8			
1100	1.9	100	5	57.6	57.3	.0872	6.11
"	"	"	"	57.0			
1311.2	1.9	100	5	55.4	55.5	.0900	2.78
"	"	"	"	55.6			

Cable horizontal and against left side of meter.

Cover on meter during run.

135 Cycles used for run.


FORT WAYNE METER

Cable horizontal and one inch from side of meter

Cover on meter during run.

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[illegible]

FORT WAYNE METER.

100 Volts. 10 Amperes. Cycles 125-140

#65181.

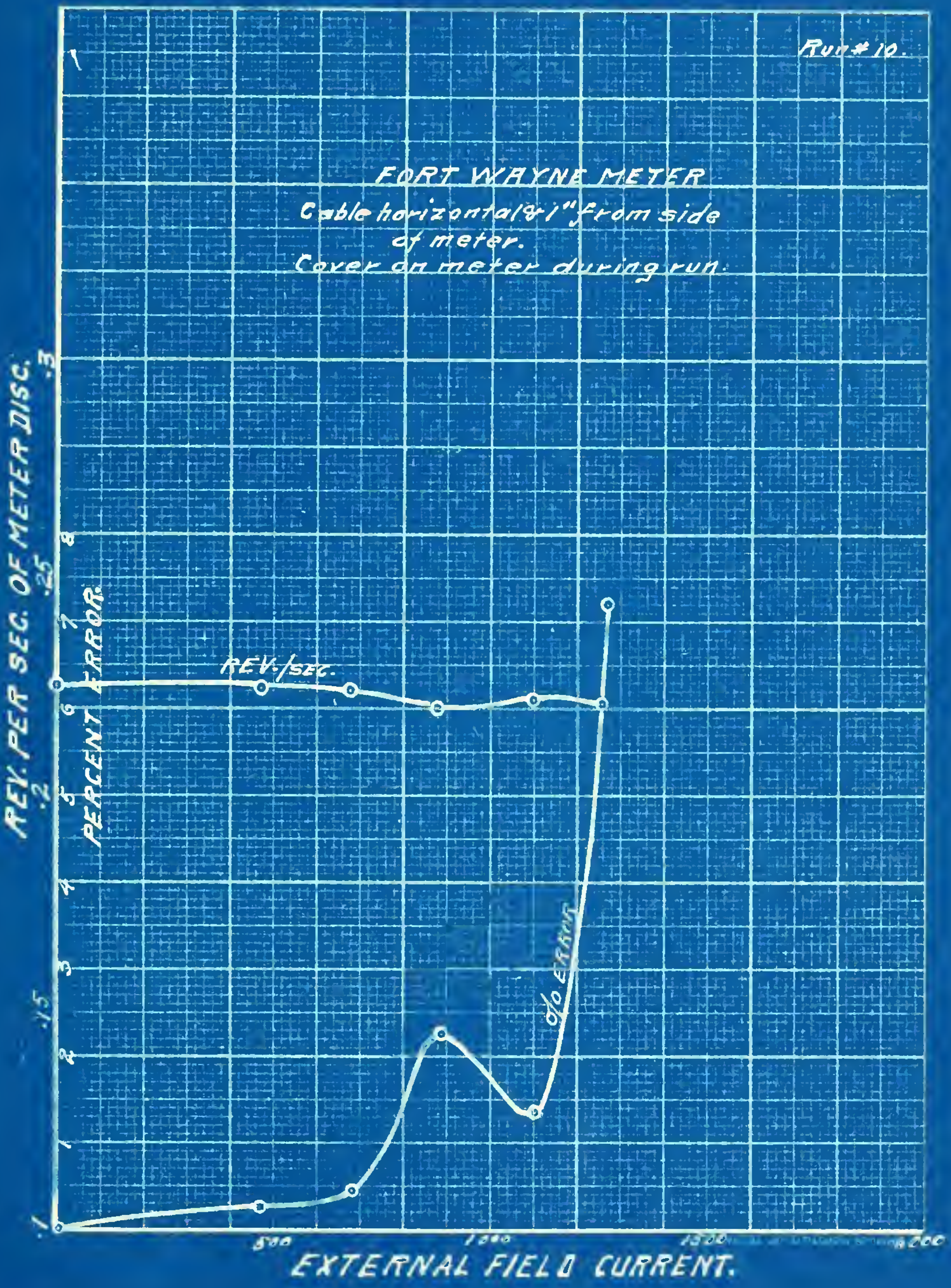
RUN #9

External field Current. (amps)	Load on Meter. (amps)	Voltage on Meter.	Rev. of Meter Disc.	Time. (sec)	Ave. Time. (sec)	Rev. per sec.	%error.
0	4.5	100	10	42.8	43.6	.229	0
"	"	"	"	44.4			
440	4.5	100	10	46.4	46.4	.2155	6.42
"	"	"	"	46.4			
673.2	4.5	100	10	47.0	47.1	.212	8.02
"	"	"	"	47.2			
880	4.5	100	10	50.4	50.1	.1995	14.9
"	"	"	"	49.8			
1100	4.5	100	10	49.6	49.266	.203	12.98
"	"	"	"	48.4			
"	"	"	"	49.8			
1293.6	4.5	100	10	49.0	48.65	.2055	11.58
"	"	"	"	49.2			
"	"	"	"	48.4			
"	"	"	"	48.0			

Cable horizontal and one inch from side of meter.

Cover on during run.

135 cycles used during run.

Run # 10.
FORT WAYNE METER
Cable horizontal & 1" from side of meter.
Cover on meter during run.
REV. PER SEC. OF METER DISC.
PERCENT ERROR.
REV./SEC.
% ERROR
1
.3
.25
.2
.15
.1
8
7
6
5
4
3
2
1
500
1000
1500
2000
EXTERNAL FIELD CURRENT.

FORT WAYNE METER.

100 Volts. 10 Amperes. Cycles 125-140

#63181.

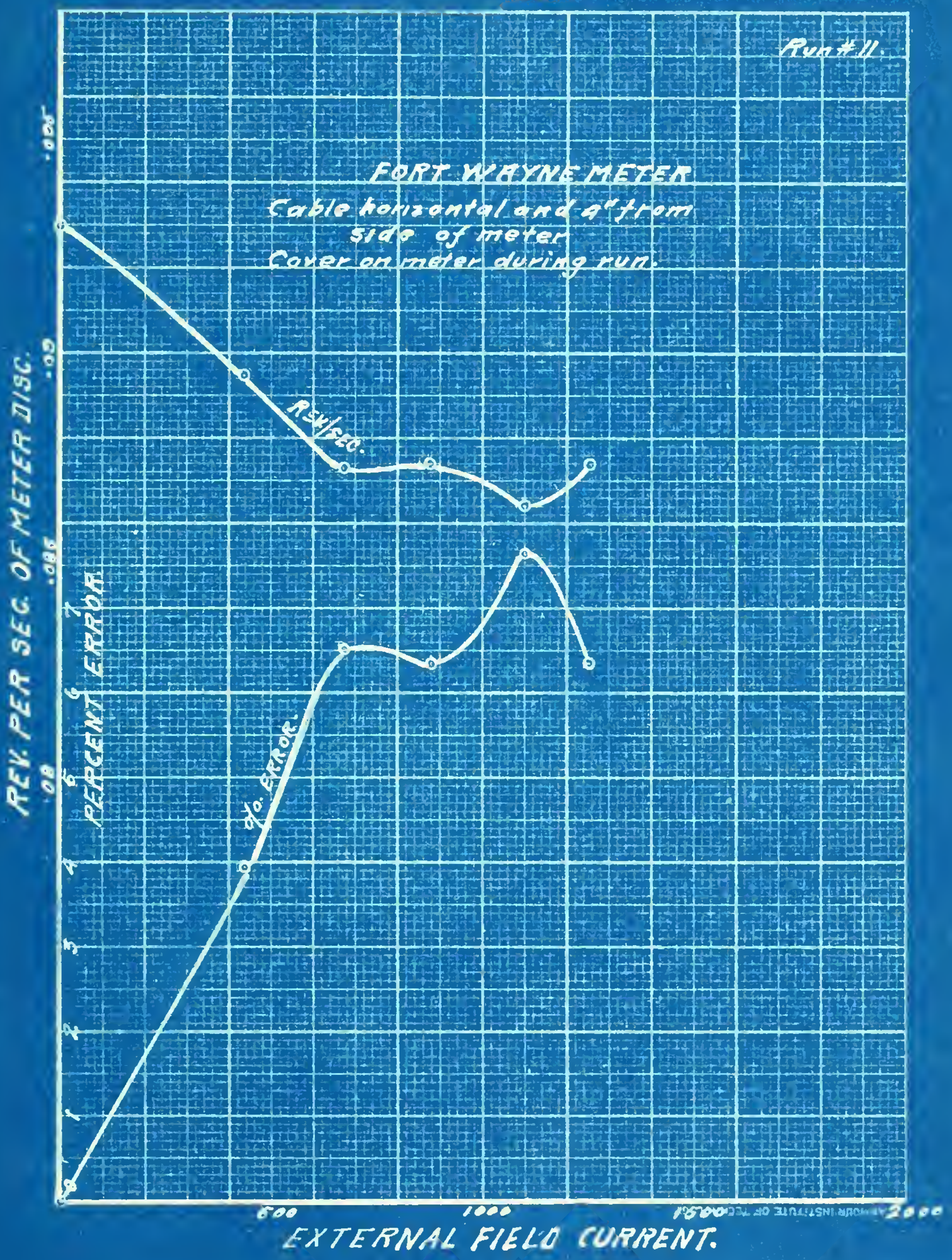
RUN #10

External field Current. (amps)	Load on Meter. (amps)	Voltage on Meter.	Rev. of Meter Disc.	Time. (sec)	Ave. Time. (sec)	Rev. per Sec.	%error.
0	4.5	100	10	44.4	44.4	.2255	0
462	4.5	100	10	44.6	44.6	.2245	.225
"	"	"	"	44.4			
682	4.5	100	10	44.6	44.6	.224	.451
"	"	"	"	44.6			
888.2	4.5	100	10	45.4	45.4	.220	2.255
"	"	"	"	45.4			
1100	4.5	100	10	45.6	45.0	.222	1.35
"	"	"	"	44.4			
1276	4.5	100	10	50.4	47.6	.210	7.2
"	"	"	"	46.2			
"	"	"	"	46.2			

Cable horizontal and one inch from side of meter.

Cover on meter during run.

135 Cycles used for run.


Run #11.
FORT WAYNE METER
Cable horizontal and 4" from
side of meter
Cover on meter during run.
REV/SEC.
% ERROR.
REV. PER SEC. OF METER DISC.
.08
.085
.09
.095
PERCENT ERROR
1
2
3
4
5
6
7
500
1000
1500
2000
EXTERNAL FIELD CURRENT.

FORT WAYNE METER.

100 Volts. 10 Amperes. Cycles 125-140.

#65181

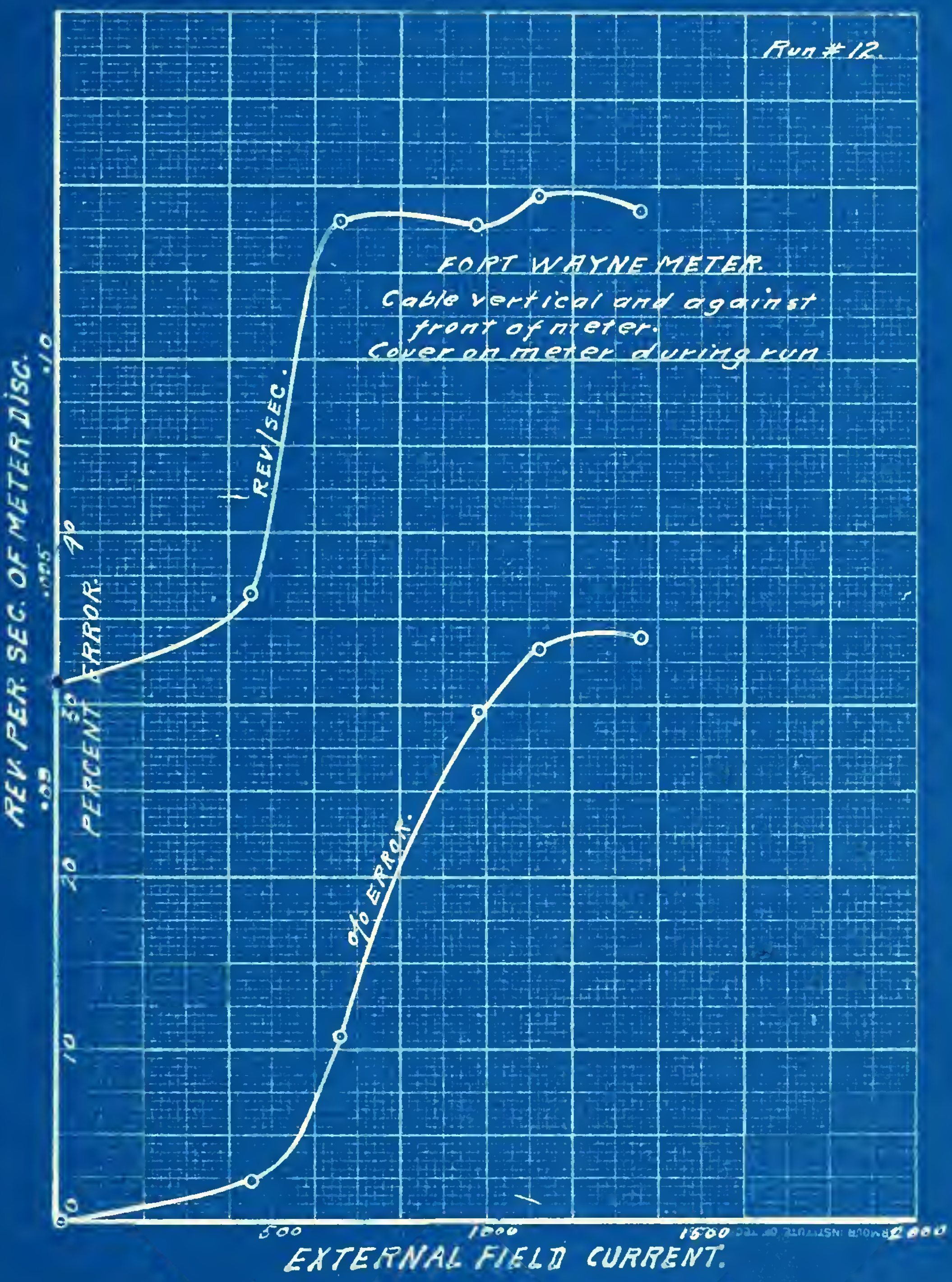
RUN #11

External field Current. (amps)	Load on Meter. (amps)	Voltage on Meter.	Rev.of Meter Disc.	Time. (sec)	Ave. Time. (sec)	Rev. per sec.	%error.
0	1.9	100	5	53.8	.093	.093	0
440	1.9	100	5	56.0	55.9	.0895	3.9
"	"	"	"	55.8			
668.8	1.9	100	5	57.2	57.3	.0874	6.5
"	"	"	"	57.4			
880	1.9	100	5	57.0	57.2	.0874	6.32
"	"	"	"	57.4			
1100	1.9	100	5	58.0	57.9	.0864	7.62
"	"	"	"	57.8			
1254	1.9	100	5	56.0	57.2	.0864	6.32
"	"	"	"	58.0			
"	"	"	"	57.6			

Cable horizontal and four inch from side of meter.

Cover on meter during run.

135 Cycles used during run.


Run # 12.
FORT WAYNE METER.
Cable vertical and against
front of meter.
Cover on meter during run
REV/SEC.
% ERROR.
REV. PER. SEC. OF METER DISC.
.09
.095
.10
PERCENT ERROR.
0
10
20
30
40
500
1000
1500
2000
EXTERNAL FIELD CURRENT.

FORT WAYNE METER.

100 Volts.   10 Amperes.   Cycles 125-140

#65181.

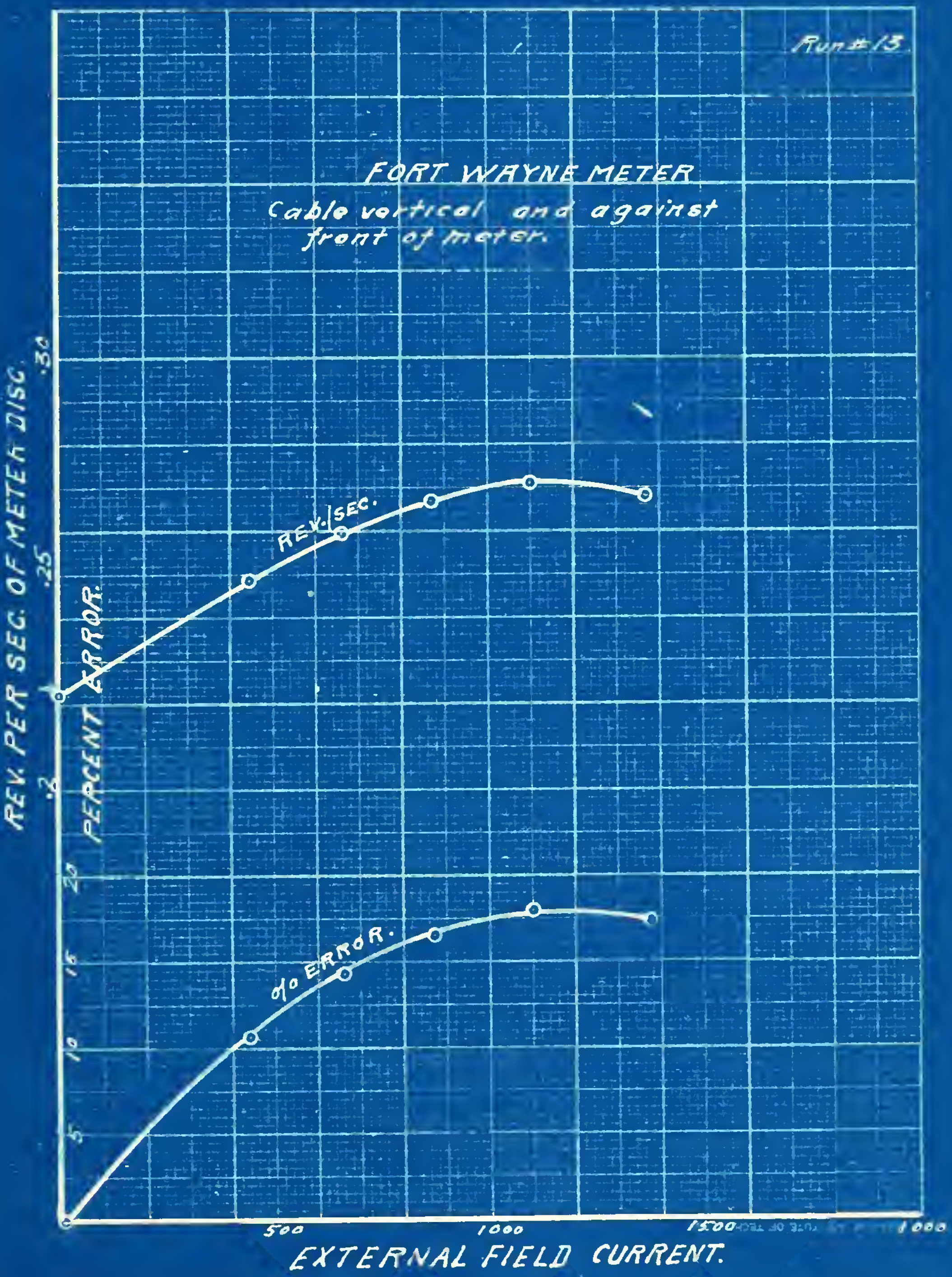
RUN #12.

External field Current. (amps)	Load on Meter. (amps)	Voltage on Meter.	Rev. of Meter Disc.	Time. (sec)	Ave. Time. (sec)	Rev. per Sec.	%error.
0	1.9	100	5	54.2	54.1	.0925	0
"	"	"	"	54.0			
449	1.9	100	5	53.0	52.8	.0946	2.40
"	"	"	"	52.6			
656	1.9	100	5	48.4	48.4	.1320	10.52.
"	"	"	"	48.4			
880	1.9	100	5	38.2	38.1	.1312	29.60
"	"	"	"	38.0			
1126	1.9	100	5	36.2	36.2	.1380	33.10
"	"	"	"	36.2			
1363	1.9	100	5	37.2	37.2	.1342	31.20
"	"	"	"	37.4			
"	"	"	"	37.0			

Cable vertical and against frontof meter

Cover on meter during run.

135 cycles used during run.



FORT WAYNE METER

Cable vertical and against
front of meter.

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FORT WAYNE METER.

100 Volts. 10 Amperes. Cycles 125-140

#65181

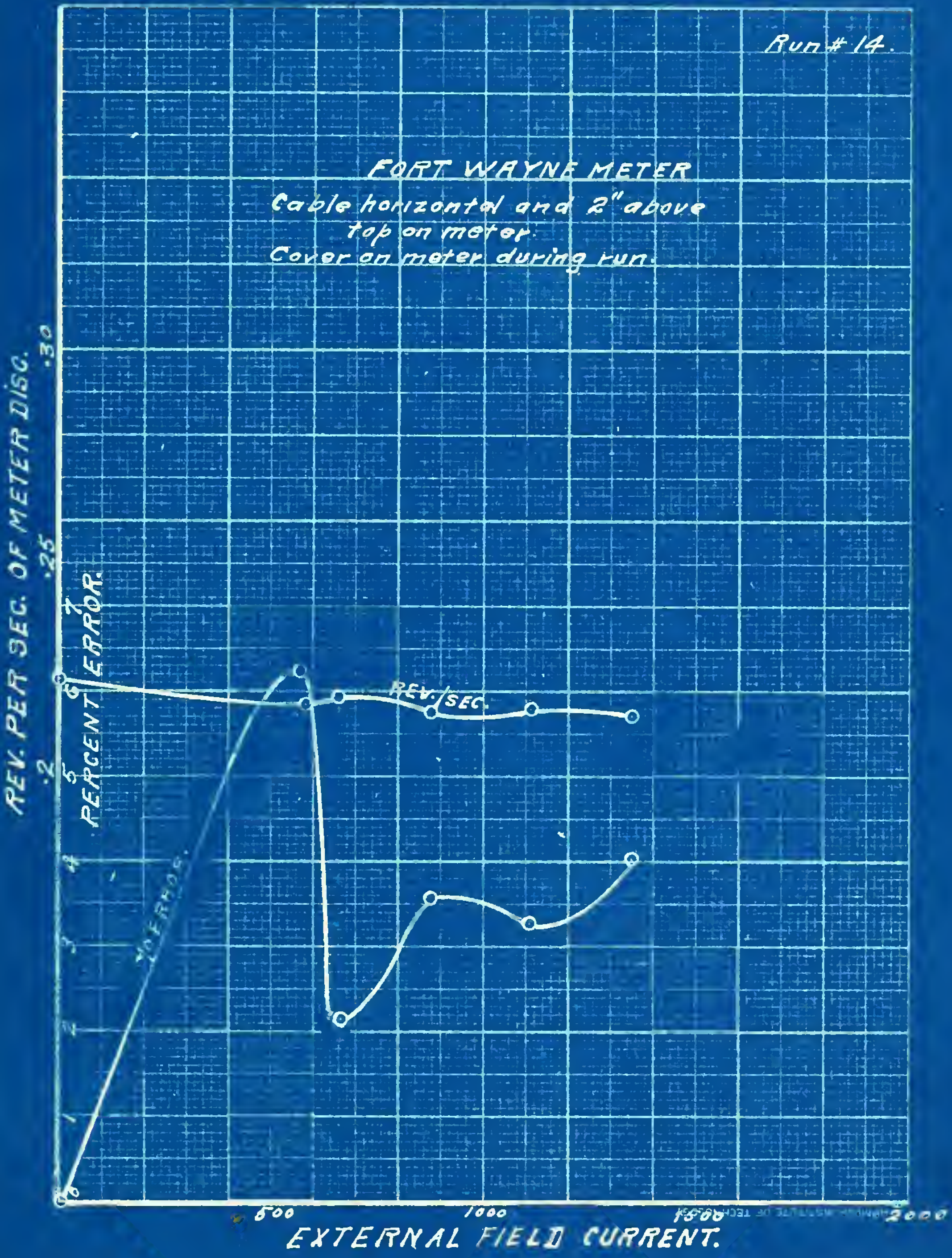
RUN #13

External field Current. (amps)	Load on Meter. (amps)	Voltage on Meter.	Rev. of Meter Disc.	Time. (sec)	Ave. Time. (sec)	Rev. per sec.	%error.
0	4.5	100	10	45.0	45.0	.222	0
440	4.5	100	10	40.0	40.2	.2485	10.67
"	"	"	"	40.4			
660	4.5	100	10	38.6	38.5	.260	14.41
"	"	"	"	38.4			
871.2	4.5	100	10	37.2	37.5	.267	16.65
"	"	"	"	37.8			
1100	4.5	100	10	37.0	36.9	.271	18.00
"	"	"	"	36.8			
1364	4.5	100	10	37.2	37.3	.268	17.10
"	"	"	"	37.4			

Cable vertical and against front of meter.

Cover on meter during run.

135 Cycles used during run.


Run # 14.
FORT WAYNE METER
Cable horizontal and 2" above
top on meter.
Cover on meter during run.
REV./SEC.
% ERROR.
REV. PER SEC. OF METER DISC.
PERCENT ERROR.
.2
.25
.30
1
2
3
4
5
6
7
500
1000
1500
2000
EXTERNAL FIELD CURRENT.

FORT WAYNE METER.

100 Volts. 10 Amperes. Cycles 125-140

#65181

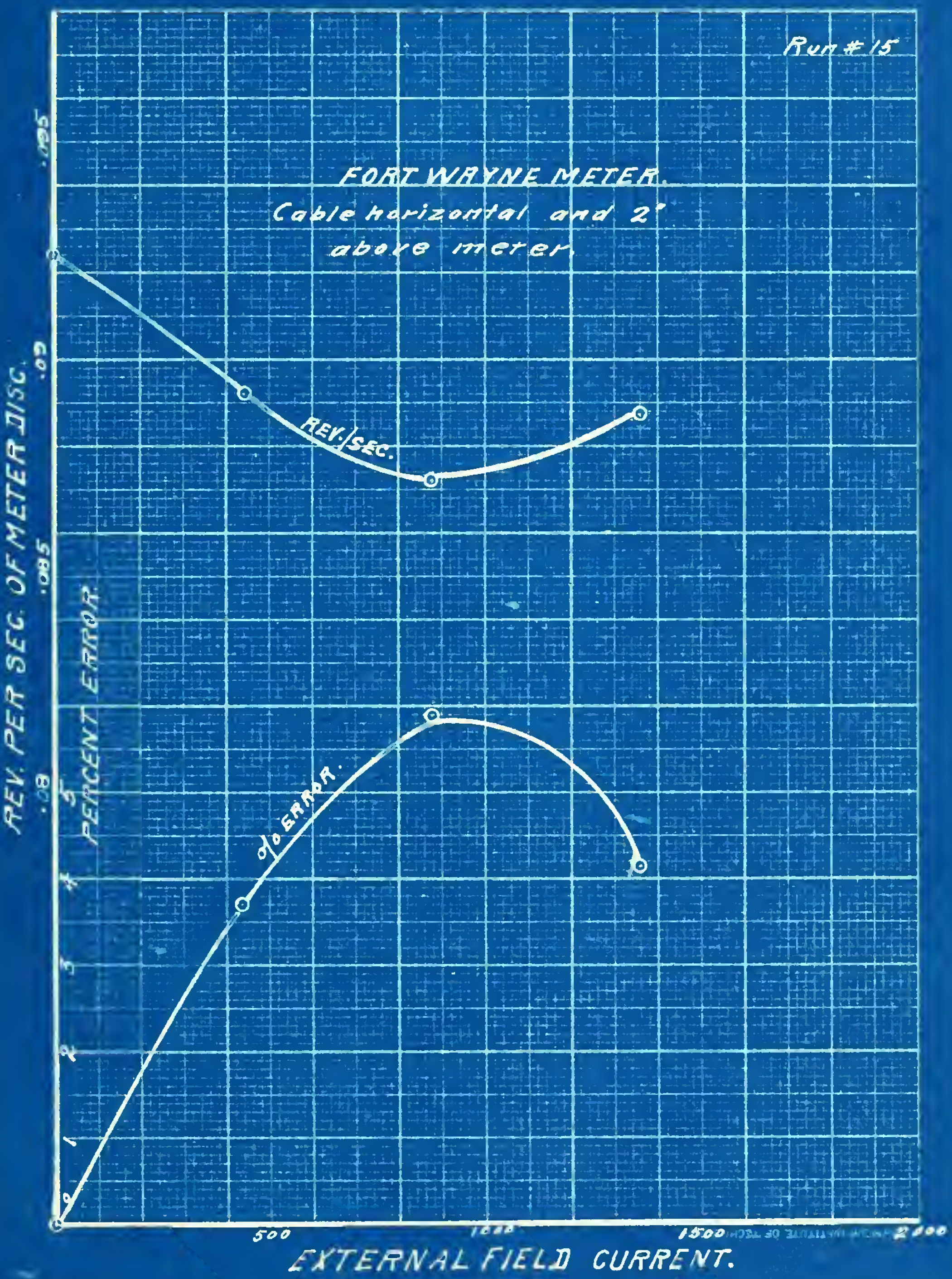
RUN #14

External field Current. (amps)	Load on Meter. (amps)	Voltage on Meter.	Rev. of Meter Disc.	Time. (sec)	Ave. Time. (sec)	Rev. per sec.	% error.
0	4.5	100	10	44.8	44.8	.223	0
"	"	"	"	44.8			
467	4.5	100	10	46.0	46.6	.217	6.24
"	"	"	"	45.5			
"	"	"	"	46.5			
660	4.5	100	10	45.8	45.77	.219	2.16
"	"	"	"	45.7			
"	"	"	"	45.8			
890	4.5	100	10	46.4	46.4	.215	3.15
"	"	"	"	46.4			
1110	4.5	100	10	46.3	46.27	.216	3.28
"	"	"	"	46.2			
"	"	"	"	46.3			
1342	4.5	100	10	46.6	46.6	.2145	4.01
"	"	"	"	46.6			

Cable horizontal and two inches above top on meter.

Cover on during run.

135 Cycles used during run.


Run # 15
FORT WAYNE METER.
Cable horizontal and 2"
above meter.
REV./SEC.
% ERROR.
REV. PER SEC. OF METER DISC.
PERCENT ERROR.
.095
.09
.085
.08
1
2
3
4
5
500
1000
1500
2000
EXTERNAL FIELD CURRENT.

FORT WAYNE METER.

100 Volts. 10 Amperes. Cycles 125-140

#65181.

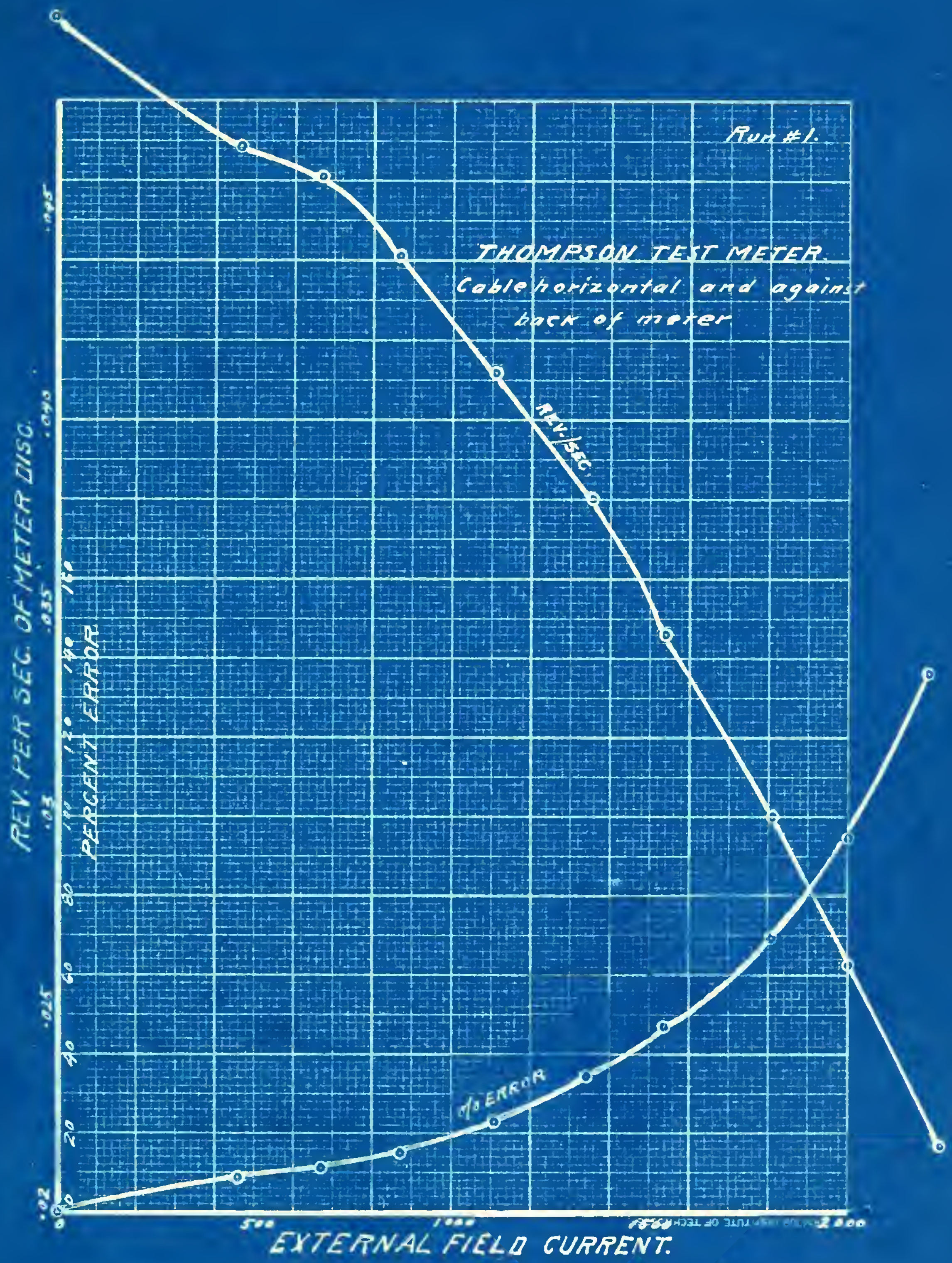
RUN #15

External field Current. (Amps)	Load on Meter. (Amps)	Voltage on Meter.	Rev. of Meter Disc.	Time. (sec)	Ave. Time. (sec)	Rev. per Sec.	%error.
0	2.5	100	5	54.2	54.2	.0924	0
"	"	"	"	54.2			
"	"	"	"	54.2			
440	2.5	100	5	56.1	56.03	.0892	3.7
"	"	"	"	56.0			
"	"	"	"	56.0			
880	2.5	100	5	57.4	57.4	.0872	5.9
"	"	"	"	57.4			
"	"	"	"	57.4			
1360	2.5	100	5	56.4	56.43	.0887	4.12
"	"	"	"	56.5			
"	"	"	"	56.4			

Cable horizontal and two inches above top on meter.

Cover on meter during run.

135 Cycles used during run.


Run #1.
THOMPSON TEST METER.
Cable horizontal and against back of meter
REV./SEC.
% ERROR
REV. PER SEC. OF METER DISC.
.02
.025
.03
.035
.040
.045
PERCENT ERROR
0
20
40
60
80
100
120
140
160
EXTERNAL FIELD CURRENT.
0
500
1000
1500
2000

ARMOUR
INSTITUTE OF TECHNOLOGY
[illegible]

THOMPSON TEST METER.

Volts 110.   20 Amperes.   Cycles 25-60

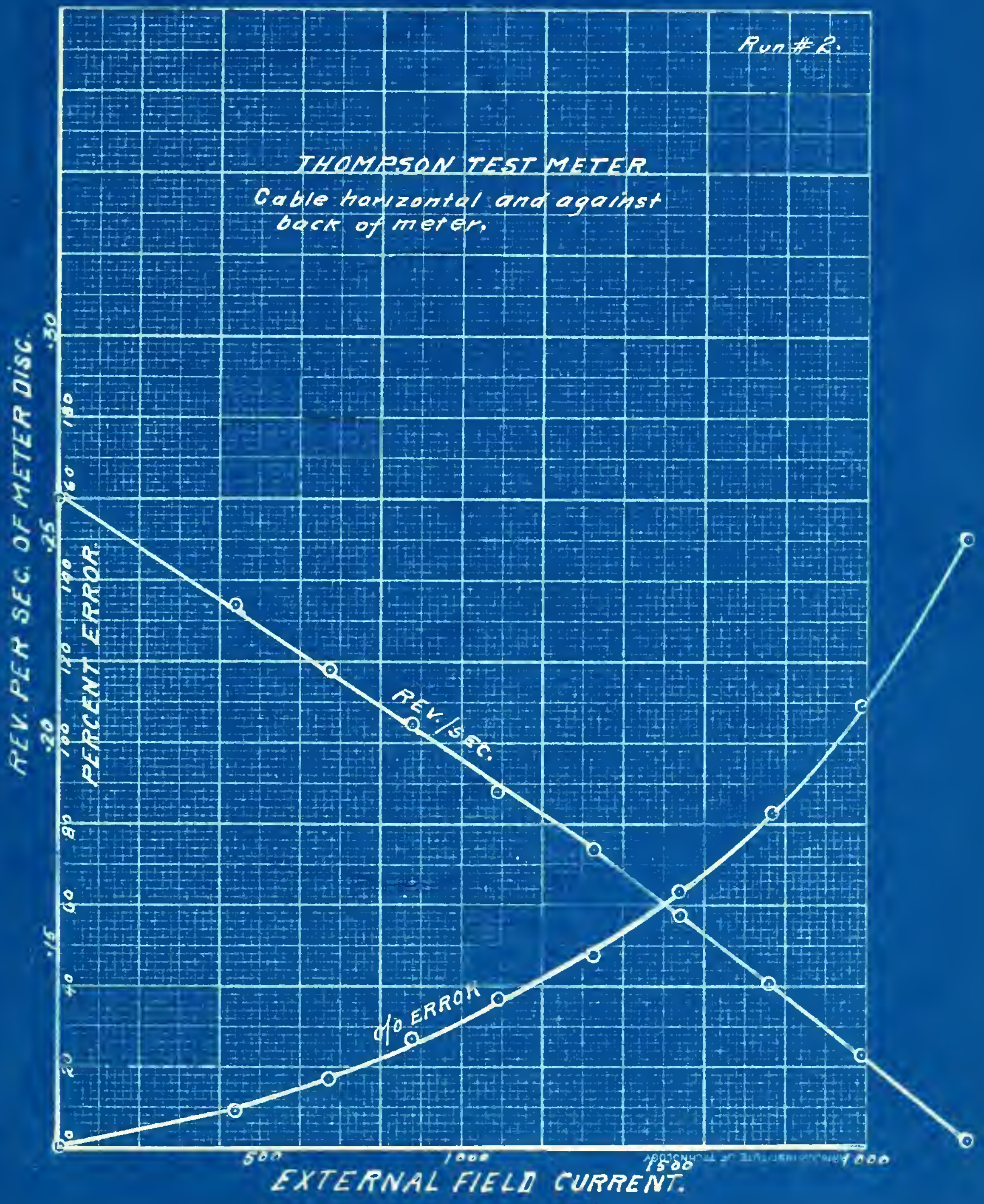
#1506564.

RUN #1

External field Current. (amps)	Load on Meter. (amps)	Voltage on Meter.	Rev. of Meter Disc.	Time. (sec)	Ave. Time. (sec)	Rev. per sec.	% error.
0	1.9	100	5	99.0	98.0	.051	0
"	"	"	"	97.0			
457.6	1.9	100	5	106.6	106.6	.0469	8.77
664.1	1.9	100	5	108.4	108.4	.0461	10.61
875.6	1.9	100	5	113.2	113.2	.0441	15.5
1113.2	1.9	100	5	121.2	121.2	.0412	23.6
1342	1.9	100	5	131.6	131.6	.038	[illegible]
[illegible]	1.9	100	5	[illegible]	[illegible]	.0346	47.4
1804	1.9	100	5	166.4	166.4	.030	69.7

Cable horizontal and against back of meter.

60 Cycles used during run.

Run #2.
THOMPSON TEST METER.
Cable horizontal and against back of meter.
REV. PER SEC. OF METER DISC.
.30
.25
.20
.15
PERCENT ERROR.
180
160
140
120
100
80
60
40
20
0
REV./SEC.
% ERROR
500
1000
1500
2000
EXTERNAL FIELD CURRENT.

ARMOUR
INSTITUTE OF TECHNOLOGY
[illegible]

THOMPSON TEST METER.

Volts 110 20 Amperes. Cycles25-60

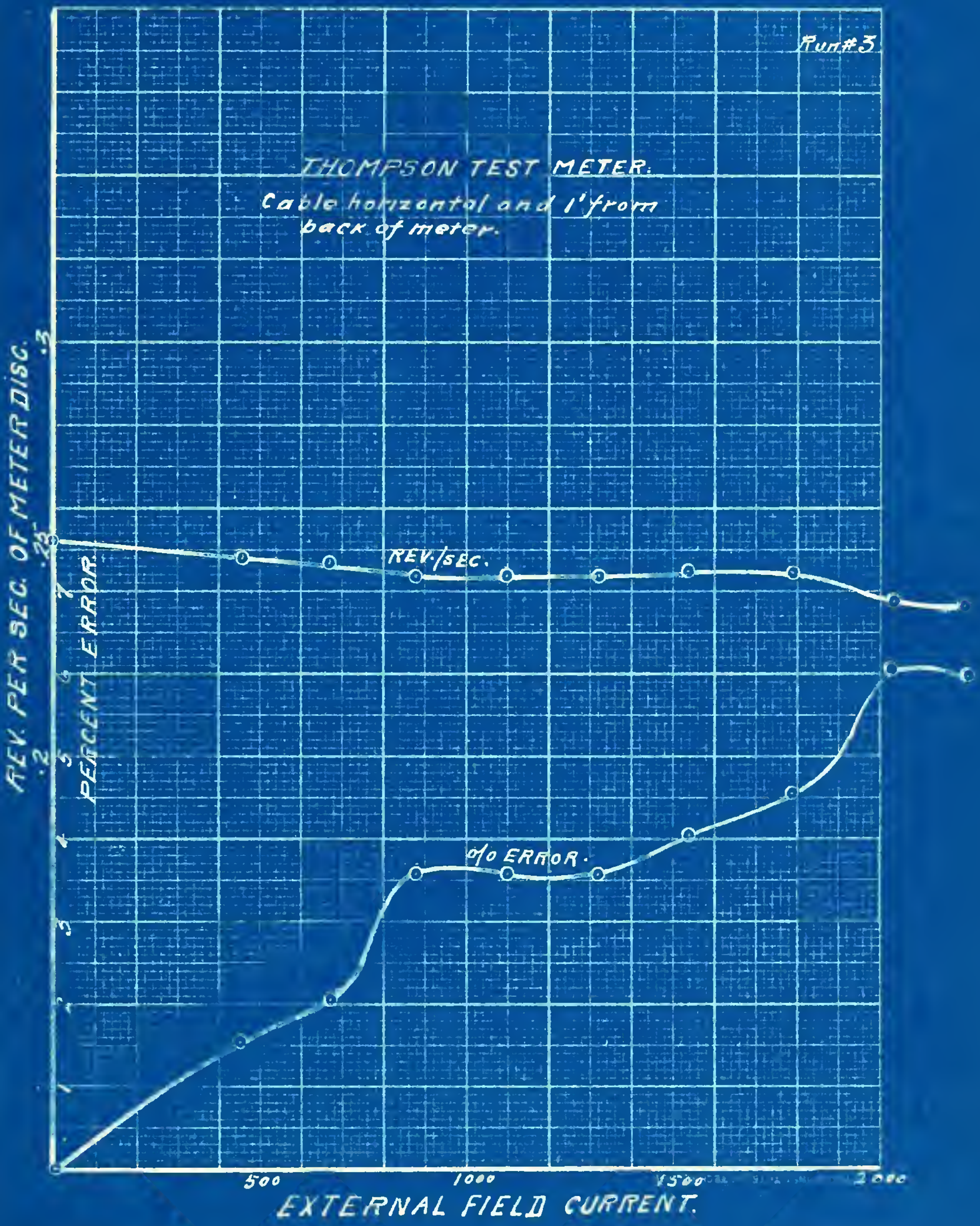
#1506564.

RUN #2

External field Current. (amps)	Load on Meter. (amps)	Voltage on Meter.	Rev. of Meter Disc.	Time. (sec)	Ave. Time. (sec)	Rev. per Sec.	%error.
0	.9	100	10	39.0	39.0	.256	0
"	"	"	"	39.0			
440	9	100	10	42.6	42.7	.234	9.49
"	"	"	"	42.8			
673.2	9	100	10	46.0	45.9	.218	17.09
"	"	"	"	45.8			
880	9	100	10	48.8	48.8	.2049	25.1
"	"	"	"	48.8			
1091.2	9	100	10	53.2	53.1	.188	36.15
"	"	"	"	53.0			
1324.4	9	100	10	57.4	57.6	.1735	47.7
"	"	"	"	57.8			
1540	9	100	10	64.0	63.8	.1567	63.5
"	"	"	"	63.6			
1764.4	9	100	10	71.4	71.3	.1402	82.75
"	"	"	"	71.2			
1984.4	9	100	10	81.4	81.4	.123	108.4
"	"	"	"	81.4			
2244	9	100	10	98.0	98.0	.102	151.0
"	"	"	"	98.0			

Cable horizontal and against back of meter.

60 Cycles used during run.


Run #3
THOMPSON TEST METER.
Cable horizontal and 1' from back of meter.
REV. PER SEC. OF METER DISC.
.3
.25
.2
PERCENT ERROR
7
6
5
4
3
2
1
REV./SEC.
o/o ERROR.
500
1000
1500
2000
EXTERNAL FIELD CURRENT.

THOMPSON TEST METER.

Volts 110. 20 Amperes. Cycles 125-140

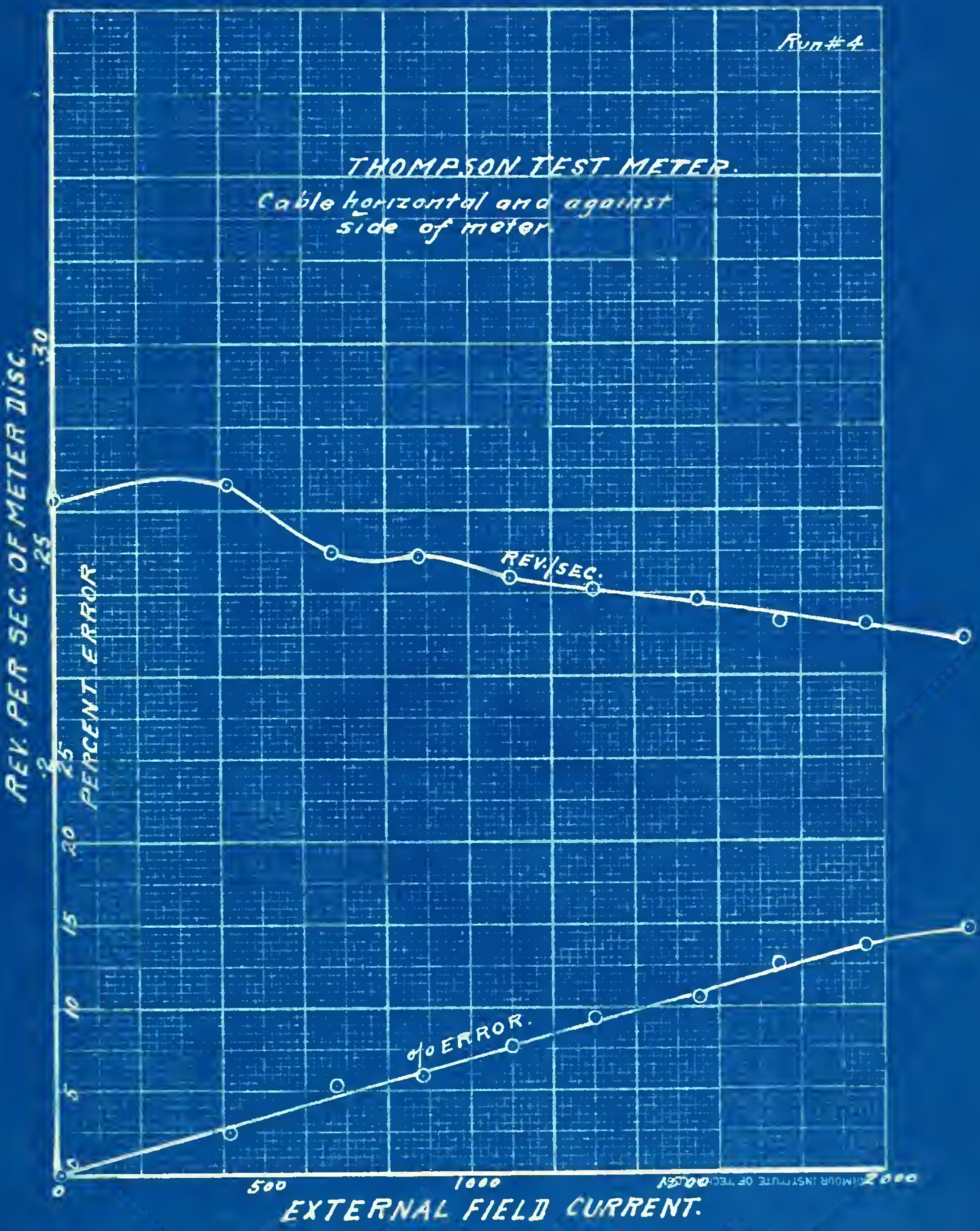
#1506564.

RUN #3.

External field Current. (amps)	Load on Meter. (amps)	Voltage on Meter.	Rev. of Meter Disc.	Time. (sec)	Ave. time. (sec)	Rev. per Sec.	%error.
0	9	100	10	39.6	39.6	.252	0
453	9	100	10	40.2	40.2	.2485	1.514
674	9	100	10	40.4	40.4	.2475	2.02
880	9	100	10	41.0	41.0	.244	3.535
1100	9	100	10	41.0	41.0	.244	3.535
1320	9	100	10	41.0	41.0	.244	3.535
1540	9	100	10	41.2	41.2	.2428	4.04
1782	9	100	10	41.4	41.4	.2415	4.55
2025	9	100	10	42.0	42.0	.238	6.06
2200	9	100	10	42.2	42.2	.237	5.99

Cable horizontal and one foot from back of meter.

60 Cycles used during run.


Run #4
THOMPSON TEST METER.
Cable horizontal and against
side of meter.
REV. PER SEC. OF METER DISC.
.30
.25
.2
PERCENT ERROR
25
20
15
10
5
0
REV./SEC.
% ERROR.
0
500
1000
1500
2000
EXTERNAL FIELD CURRENT.

THOMSON TEST METER.

Volts 110. 20 Amperes. Cycles 125-140

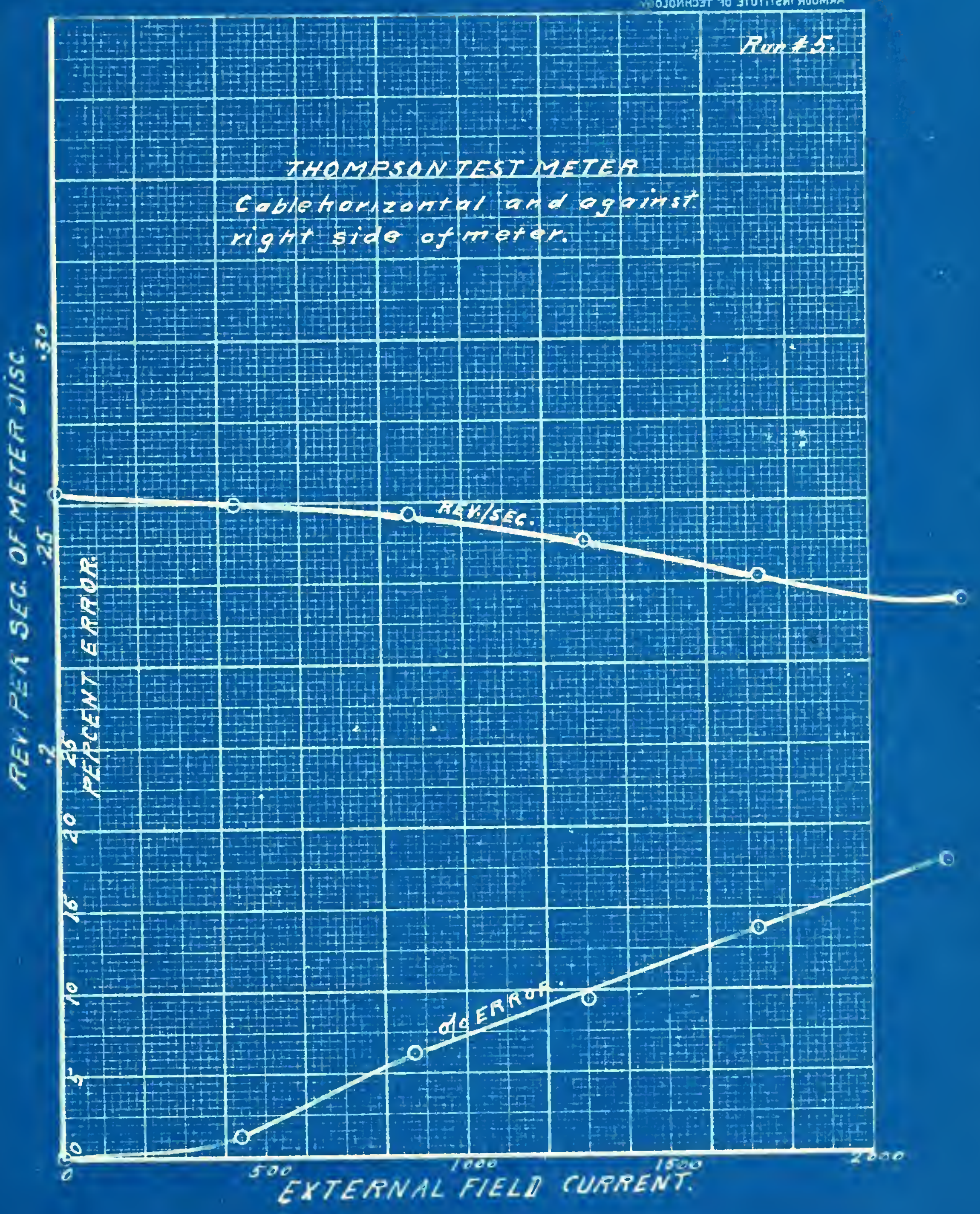
#1506564.

RUN#4.

External field Current. (amps)	Load on Meter. (amps)	Voltage on Meter.	Rev. of Meter Disc.	Time. (sec)	Ave. Time. (sec)	Rev. per sec.	%error.
0	9	100	10	38.0	38.0	.263	0
418	9	100	10	39.0	39.0	.2662	2.63
673	9	100	10	40.0	40.0	.2500	5.27
880	9	100	10	40.2	40.2	.2490	5.80
1095	9	100	10	41.0	41.0	.2440	7.0
1307	9	100	10	41.6	41.6	.2405	9.47
1555	9	100	10	42.0	42.0	.2382	10.50
1743	9	100	10	42.8	42.8	.2330	12.65
1960	9	100	10	43.0	43.0	.2325	13.15
2200	9	100	10	43.6	43.6	.2292	14.72
"	"	"	"	43.6			

Cable horizontal and against side of meter

60 Cycles used during run.



Run # 5.

THOMPSON TEST METER

Cable horizontal and against right side of meter.

[illegible]
INSTITUTE OF [illegible]
LIBRARY.

THOMPSON TEST METER.

Volts 110. 20 Amperes. Cycles 125-140.

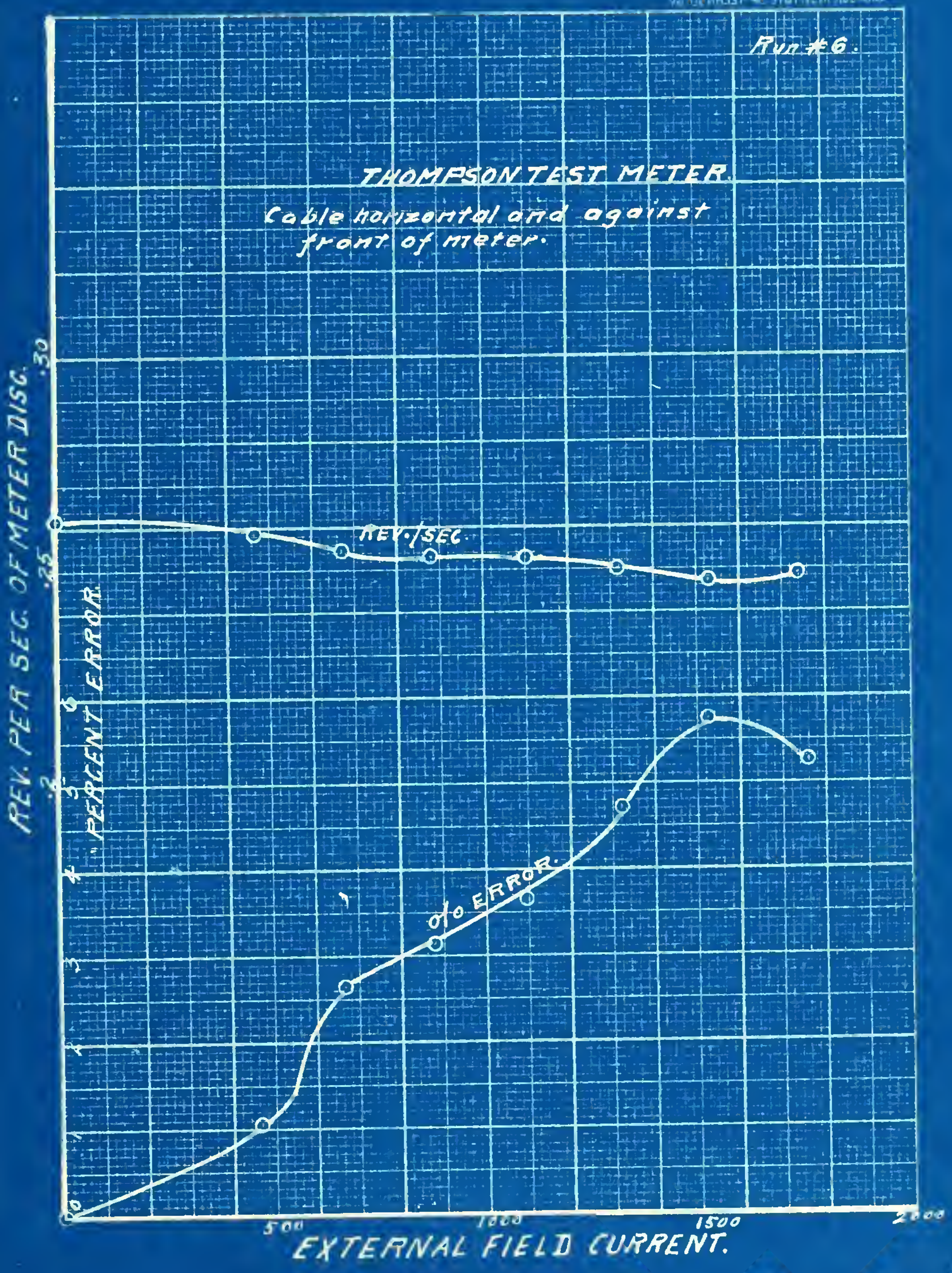
#1506564.

RUN #5

External field Current. (amps)	Load on Meter. (amps)	Voltage on Meter.	Rev. of Meter Disc.	Time. (sec)	Ave. Time. (sec)	Rev. per sec.	%error.
0	9	100	10	38.2	38.2	.262	0
462	9	100	10	38.6	38.6	.2590	1.05
675	9	100	10	39.2	39.2	.255	2.62
880	9	100	10	39.4	39.4	.2536	3.14
1100	9	100	10	39.6	39.6	.2525	3.67
1320	9	100	10	40.0	40.0	.2500	4.72
1530	9	100	10	40.4	40.4	.2472	5.77
1760	9	100	10	40.2	40.2	.2490	5.24.

Cable horizontal and against front of meter.

60 Cycles used during run.


Run #6.
THOMPSON TEST METER.
Cable horizontal and against front of meter.
REV./SEC.
% ERROR.
REV. PER SEC. OF METER DISC.
PERCENT ERROR.
.30
.25
.2
6
5
4
3
2
1
0
500
1000
1500
2000
EXTERNAL FIELD CURRENT.

THOMPSON TEST METER.

Volts 110. 20 Amperes. Cycles 125-140

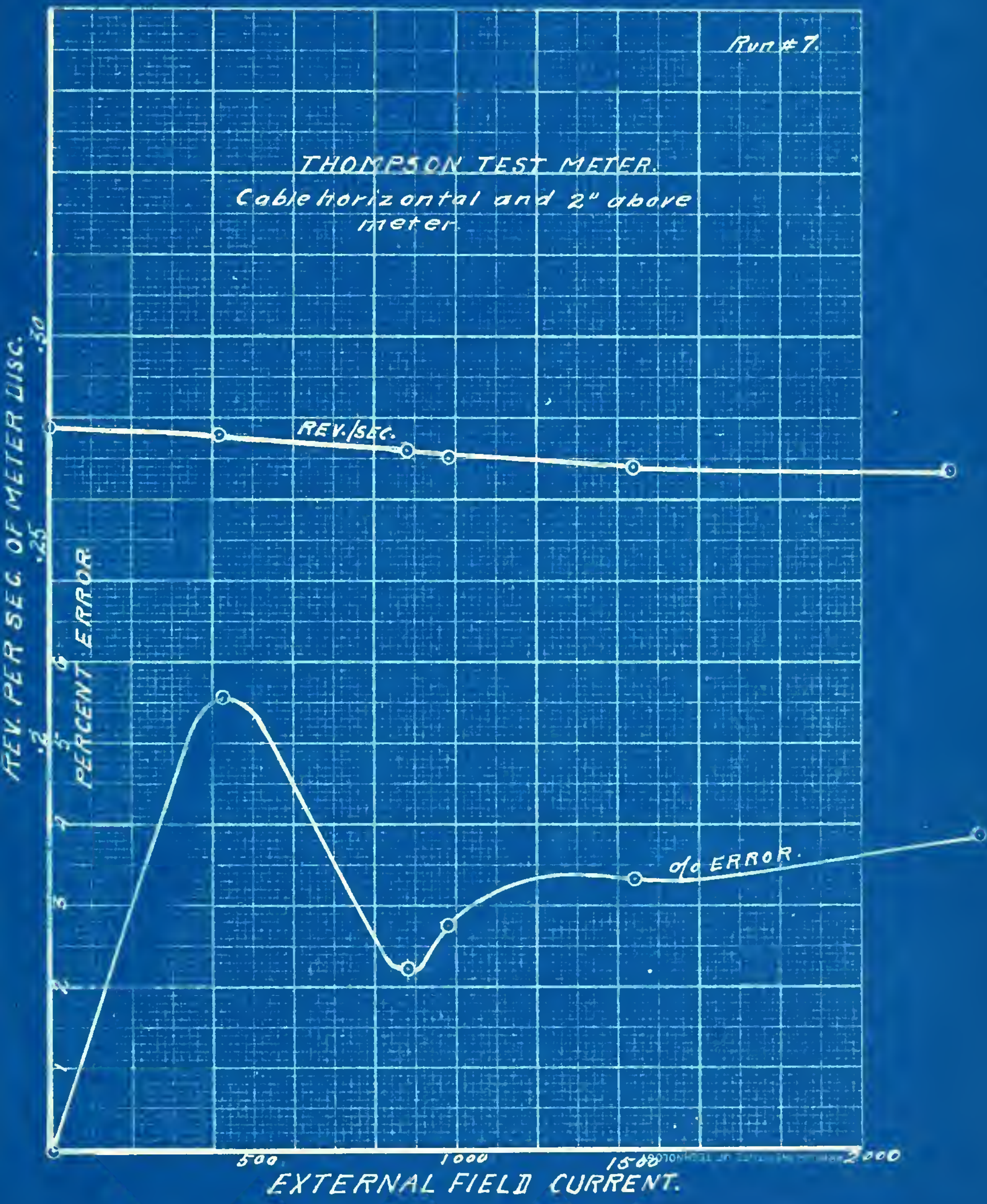
#1506564.

RUN #6.

External field Current. (amps)	Load on Meter. (amps)	Voltage on Meter.	Rev. of Meter Disc.	Time. (sec)	Ave. Time. (sec)	Rev. per sec.	%error.
0	9	100	10	38.0	38.0	.263	0
440	9	100	10	38.4	38.4	.2602	1.05
871.2	9	100	10	40.4	40.4	.2475	6.32
1306.8	9	100	10	41.6	41.6	.2405	9.46
1720.4	9	100	10	43.2	43.2	.2315	13.69
2200	9	100	10	44.6	44.6	.224	17.34

Cable horizontal and against right side of meter.

60 Cycles used during run.


Run #7.
THOMPSON TEST METER.
Cable horizontal and 2" above meter.
REV. PER SEC. OF METER DISC.
PERCENT ERROR
.30
.25
.2
6
5
4
3
2
1
REV./SEC.
% ERROR.
500
1000
1500
2000
EXTERNAL FIELD CURRENT.

THOMPSON TEST METER.

Volts 110. 20 Amperes. Cycles 125-140

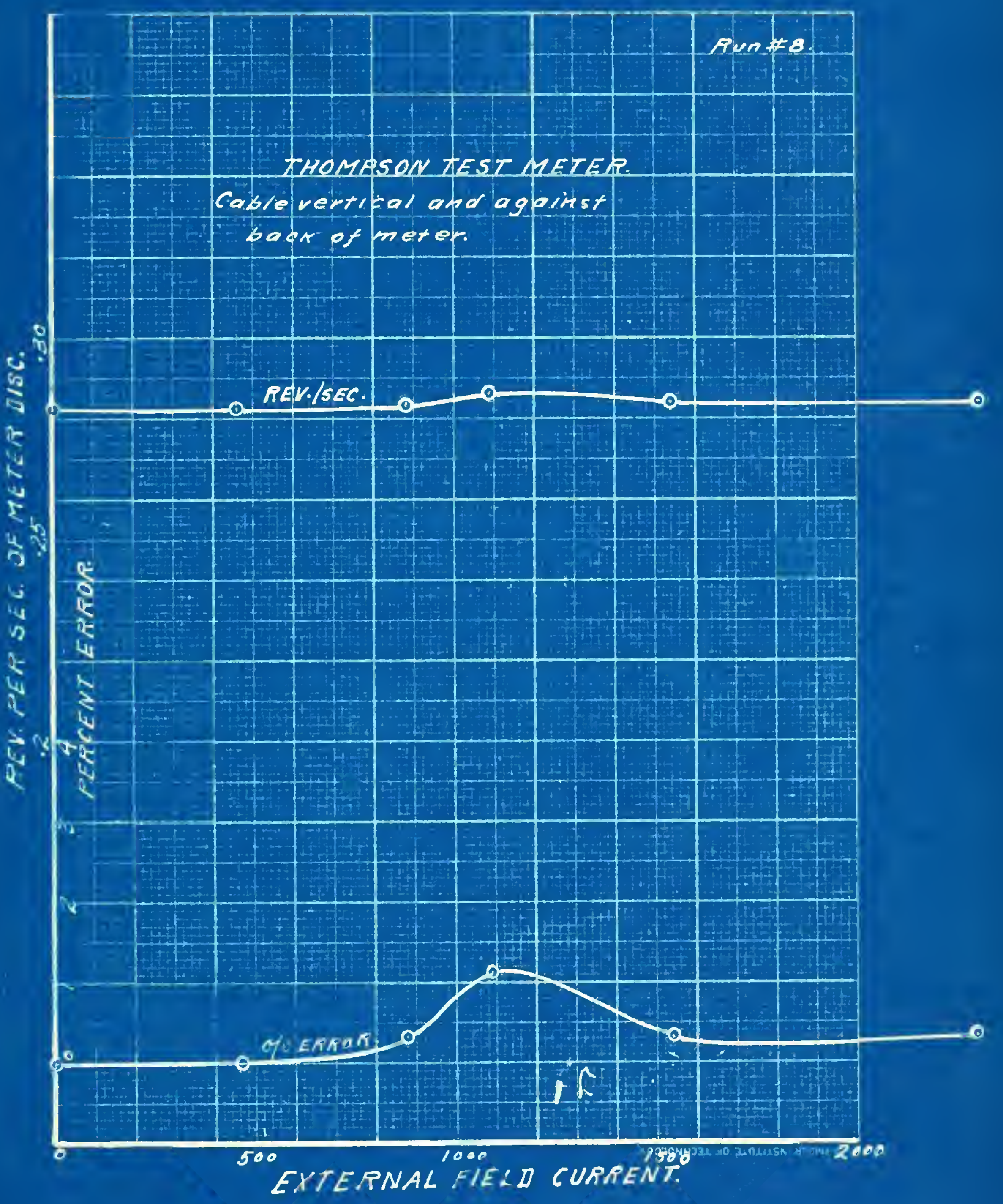
#1506564.

RUN # 7

External field Current. (amps)	Load on Meter. (amps)	Voltage on Meter.	Rev. of Meter Disc.	Time. (sec)	Ave. Time. (sec)	Rev. per Sec.	%error.
0	9	100	10	36.0	36.0	.278	0
"	"	"	"	36.0			
422.4	9	100	10	36.2	36.2	.276	0.55
880	9	100	10	36.8	36.8	.272	2.22
981.2	9	100	10	37.0	37.0	.270	2.78
1540	9	100	10	37.2	37.2	.2685	3.33
2288	9	100	10	37.4	37.4	.2675	3.885

Cable horizontal and two inches above meter.

60 Cycles used during run.


Run #8.
THOMPSON TEST METER.
Cable vertical and against back of meter.
REV./SEC.
% ERROR.
REV. PER SEC. OF METER DISC.
PERCENT ERROR
.30
.25
.2
4
3
2
1
0
0
500
1000
1500
2000
EXTERNAL FIELD CURRENT.

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THOMPSON TEST METER.

Volts 110. 20 Amperes. Cycles 125-140

#1506564.

RUN #8

External field Current. (amps)	Load on Meter. (amps)	Voltage on Meter.	Rev. of Meter Disc.	Time. (sec)	Ave. Time. (sec)	Rev. per sec.	% error.
0	9	100	10	35.4	35.4	.2825	0
462	9	100	10	35.4	35.4	.2825	0
880	9	100	10	35.2	35.2	.284	.565
1091	9	100	10	35.0	35.0	.286	1.130
1540	9	100	10	35.2	35.2	.284	.565
2288	9	100	10	35.2	35.2	.284	.565.

Cable vertical and against back of meter.

60 Cycles used during run.